HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII
Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE UNIVERSITY OF HAWAII

BULLETIN No. 64

THE PIGEON PEA (CAJANUS INDICUS) ITS IMPROVEMENT, CULTURE AND UTILIZATION IN HAWAII

By
F. G. KRAUSS
Director of Cooperative Agricultural Extension Service
University of Hawaii

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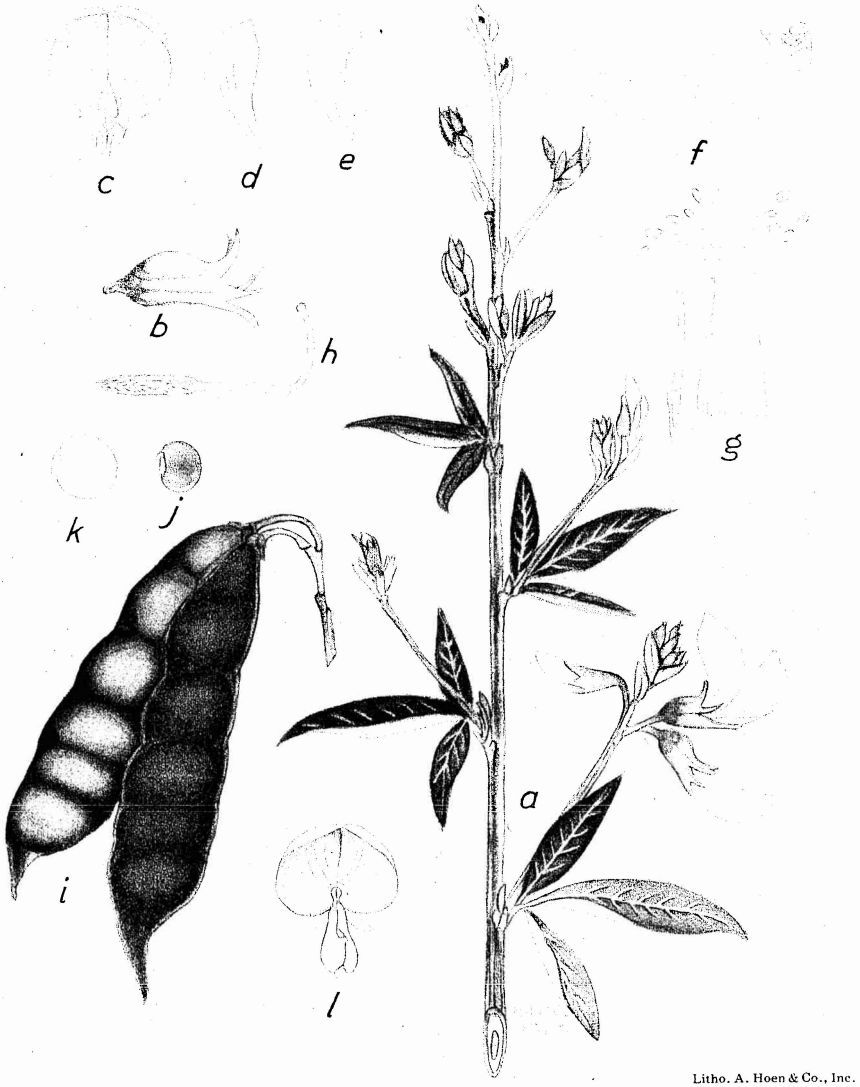

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CAJANUS INDICUS (NATURAL SIZE)

a, Inflorescence; *b*, calyx, × 2; *c*, standard; *d*, wing petal; *e*, keel-petal; *f* and *g*, androecium, × 2, *h*, gynoecium, × 2; *i*, legume; *j*, seed; *k*, green seed used for culinary purposes; and *l*, front view of entire flower

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CONTENTS

INTRODUCTION

Since the establishment of the Hawaii Agricultural Experiment Station in 1901, which marks the first systematized effort to investigate scientifically the possibilities of diversified agriculture in Hawaii, more than 100 species and many hundreds of varieties of leguminous field crops have been grown for comparison at the central station in Honolulu, island of Oahu, and at the several substations on the other islands of the Territory of Hawaii. Among these crops the pigeon pea was first grown between the years 1906 and 1908 (*11, p. 21; 12*).[3] The variety known at the station as No. 218 (fig. 1), although badly mixed in type, made an exceptionally vigorous vegetative growth by the time it began to flower and to set pods, and an unusually heavy yield of seed when the pods matured as compared with the numerous other legumes under test. (Fig. 2.)

Of three test rows, each 100 feet long, the middle row produced 102 pounds of prime shelled seed within eight months from time of

[1] This bulletin is a revision of and supersedes Bulletin No. 46, The Pigeon Pea (*Cajanus indicus*) : Its Culture and Utilization in Hawaii, by F. G. Krauss.
[2] Formerly agronomist of the Hawaii Agricultural Experiment Station.
[3] Italic numbers in parentheses refer to Ltierature Cited, p. 42.

planting. This was at the rate of 1.02 pounds per running foot of row. If calculated to acre yields, with rows spaced 10 feet apart, the first crop would have amounted to approximately 2¼ tons per acre of shelled seed. Two subsequent crops of pods were harvested within the succeeding 12 months, the combined yield approximating that of the first crop. In other words, this unique perennial legumi-

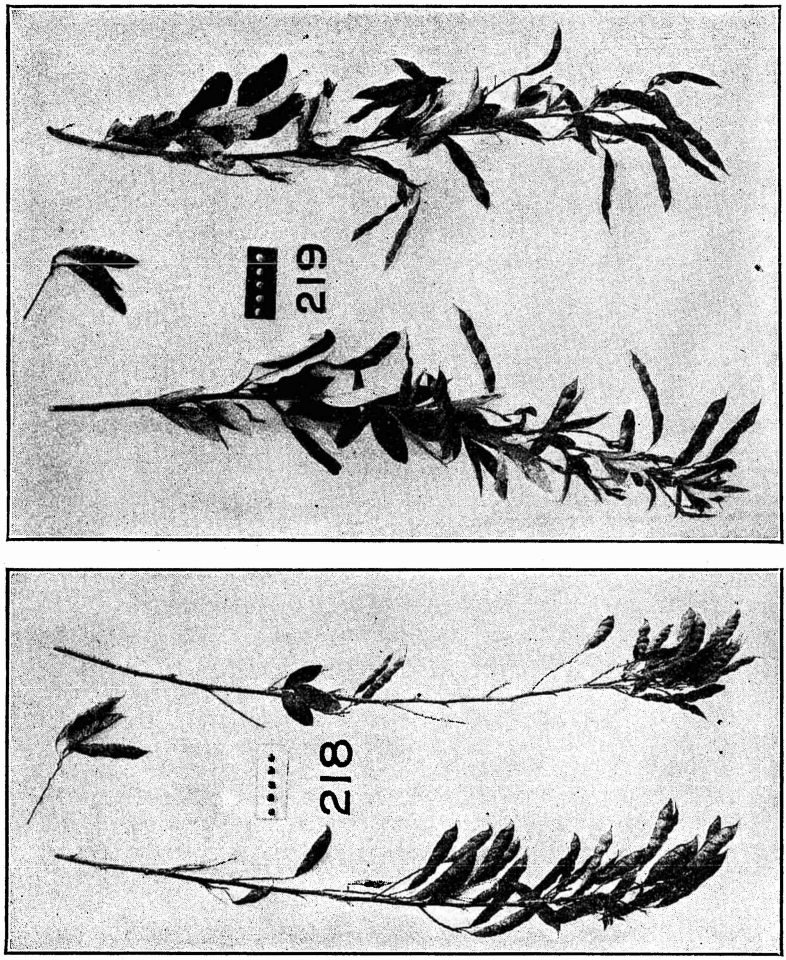

FIGURE 1.—Pigeon-pea varieties: Left, station variety No. 218, probably *Cajanus indicus flavus* (one-sixth natural size); and right, station variety No. 219, probably *C. indicus bicolor* (one-sixth natural size), showing mature seeds and fruited branches

nous shrub in less than two years yielded at the rate of nearly 4½ tons per acre of highly nutritious seed.

In Hawaii no other leguminous crop is known to have yielded so consistently year after year as has the pigeon pea. After 25 years of continuous culture under a wide range of soil and climatic conditions, and from near sea level to elevations approximating 3,250 feet, the crop seems to have become firmly established in the somewhat limited diversified agriculture. Approximately 10,000 acres have been cropped with pigeon peas during the last 10 years. On

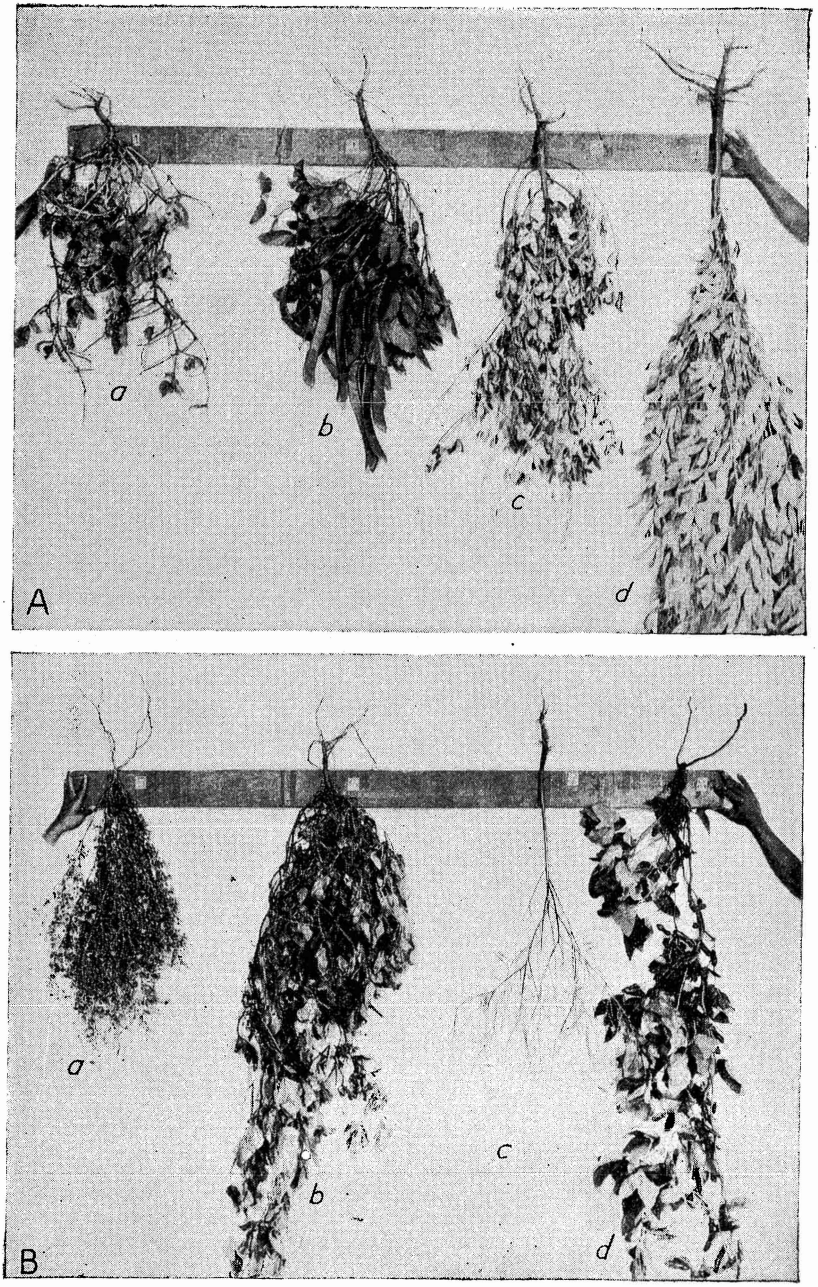

FIGURE 2.—Comparative growth of some typical leguminous plants at 5 months of age: A, *a*, cowpea; *b*, jack bean; *c*, *Crotalaria saltiana*; *d*, pigeon pea; B, *a*, alfalfa; *b*, *Phaseolus mungo*; *c*, sunn hemp; *d*, velvetbean

the island of Hawaii plantings have covered an aggregate of 3,500 acres; on Maui, 3,000 acres; on Molokai, 1,000 acres; on Oahu, 1,750 acres; on Kauai, 500 acres; and on Lanai, 250 acres. (Fig. 3.) Fully half of the crop on this area is used as pasture for fattening cattle for market, and the rest is grown mainly for rotating with pineapples and for green manure. On a limited area the crop is grown primarily for seed production. There is a fairly constant demand for the seed. It is estimated that between 10 and 20 tons of seed

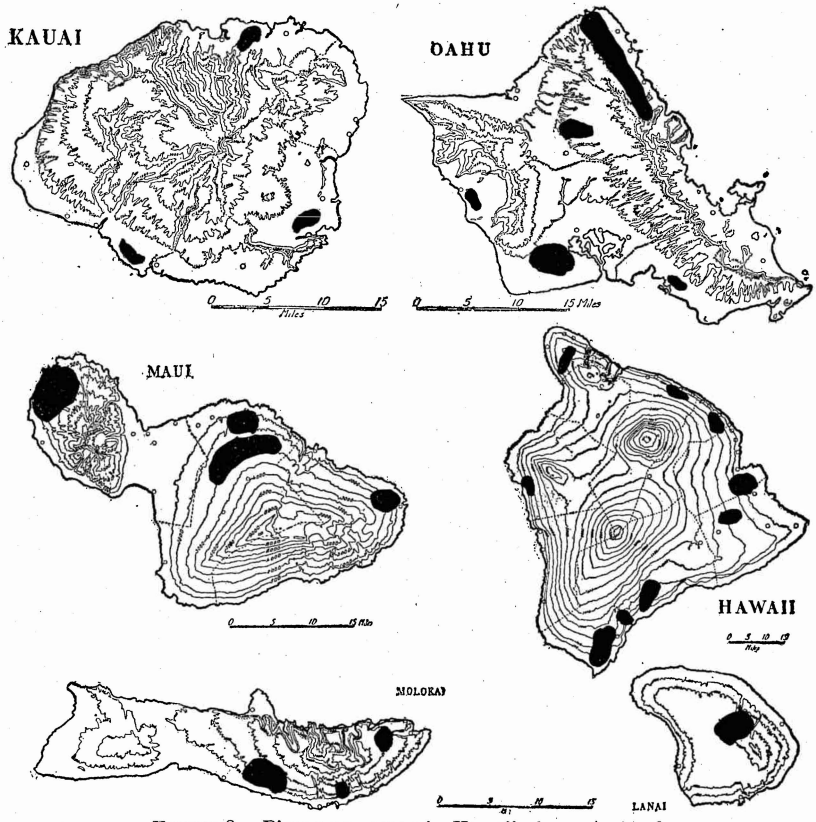

FIGURE 3.—Pigeon-pea areas in Hawaii shown in black

were sown in Hawaii in 1929. Since on an average of about 20 pounds of seed is sown per acre, probably not less than a thousand acres of land was planted with the crop in 1929.

Since the establishment of the standard variety now commonly called "New Era Strain D," a selection originating from station variety No. 218, over 100 named varieties, including many new to the islands, have been introduced from India, the Philippines, Porto Rico, and Florida. (Fig. 4.) Active breeding work was begun at the Haiku substation in 1919–20. The Hawaii Agricultural Experiment Station in Honolulu has now about 500 recorded hybrids in varying degrees of fixation under culture in duplicate plantings

under widely differing soil and climatic conditions. One new hybrid, identified as New Era Strain X, is the result of crossing New Era Strain D (*Cajanus indicus flavus*), which bears yellow flowers, matures early, and seeds heavily, with station variety No. 219 (probably *C. indicus bicolor*) (fig. 1), a tall growing, later maturing sort bearing for the most part yellow flowers tinged on the back and in the bud form with deep red. (Fig. 5.) This promising hybrid now in the fifth generation is intermediate between the two parent varieties and has closely adhered to Mendel's law genetically. New Era Strain Y is a chance hybrid, the original plant of which yielded more than 15,000 seeds. The seed of the

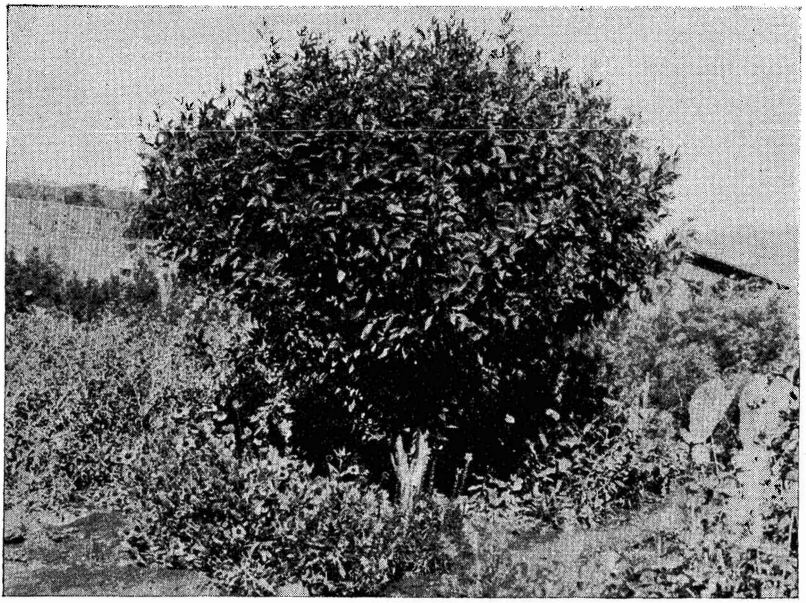

FIGURE 4.—Five-year-old ideal pigeon-pea plant of New Era Strain D standing alone and systematically pruned. It is a thing of beauty as well as of utility

original plant was small, almost spherical, and of pearly or ivory-white color. Unfortunately, much difficulty has been experienced in fixing the ideal seed type of this hybrid, succeeding generations of which range from ashy gray to almost pearly white. Size and shape of seed also vary considerably. However, the heavy yielding character has been fairly well maintained, and the hybrid gives promise of becoming a favorite culinary variety.

Within the last 9 or 10 years considerable information has been gathered on the best methods of culture for the pigeon pea and the uses to which it is best adapted. Hawaii-produced seed has now become distributed throughout the tropical and the semitropical world. Because of the potentialities of and an ever-increasing interest in the crop, this bulletin, which supersedes the previous bulletin by Krauss (*12*) has been prepared for planters in Hawaii and elsewhere.

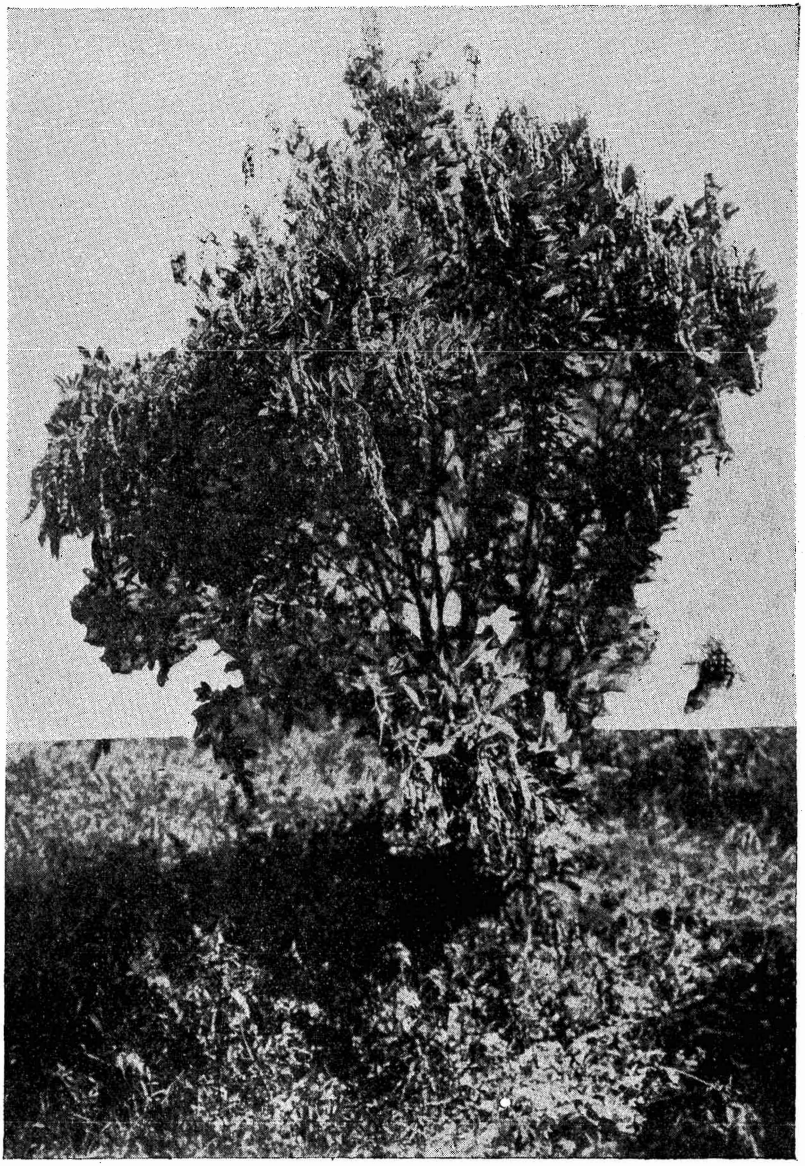

FIGURE 5.—Progenitor of a new variety. New Era Strain X F_1 (New Era Strain D, station variety No. 218, crossed with station variety No. 219). Bred at Haiku substation, 1920

BOTANY, HISTORY, AND NOMENCLATURE

The pigeon pea, botanically known as *Cajan cajan*, *Cajanus indicus*, and *Cytisus cajan*, is an erect, perennial shrub belonging to the botanical family Fabaceae, natural order Leguminosae, the fruit of which is a true pod. The only species is *Cajanus indicus*, and the two subspecies are *C. indicus flavus* and *C. indicus bicolor*. *C. indicus flavus* in some respects resembles the type in India known as "thur." It bears yellow flowers, is of semidwarf habit, and matures early. In Hawaii it is typified by station variety No. 218, from which the variety known as New Era Strain D was selected. *C. indicus bicolor* produces yellow flowers except for the dorsal side of the standard which usually is dark red with suffusions of red on the inner surface. This subspecies grows tall, may approach arborescence, in which respect it is similar to the type known in India as "arhar," and matures late. It is typified by station variety No. 219 which the bybrid New Era Strain X resembles. Whereas *C. indicus flavus* produces solid green pods and seeds of drab color similar to that of the Clay or Iron cowpea, the pods of *C. indicus bicolor* have a green background blotched with deep red or maroon, and the seed is usually distinctly speckled, with brown on a light-colored background.

The pods and the seeds of *C. indicus bicolor* are usually larger than those of *C. indicus flavus*. (Fig. 6.) Innumerable varieties have been produced by crossing the two original subspecies, with the result that every possible gradation may now be found. Some types are very dwarf, early maturing, and annual; other types are very tall, branching, arborescent, and persist for 10 or more years. Of the 590 varieties and their hybrids at the University of Hawaii farm, the height ranges from 18 inches to 12 feet, and the spread of branches from one-fourth to exceeding half the height. (Fig. 7.) Pods and seed likewise vary greatly. The pods may be 2 to 5 inches long, and almost cylindrical, or of equal length but broad and flat and with varied colors and markings. The seed may vary from the size of vetch to that of field peas. Some seed is flattish, and other seed is spherical. The color ranges from solid ivory white through brown and red to almost black, and there are various kinds of markings, especially speckled and blotched.

Most varieties produce extremely deep penetrating taproots. (Fig. 8.) These usually are directly proportional to the height of the plant, although the roots of the more compact, upright types apparently extend to the greatest depths. The leaves are pinnately trifoliate, light green and glabrous above, and silvery pubescent below. The foliage varies in growth from sparse to very dense. Under optimum cultural conditions all varieties branch freely, ranging from very upright to very spreading, and drooping usually only when heavy in pod.

The pods, although varying greatly in size and in shape in the different varieties, usually are only three to six seeded. With the approach of maturity the pods become constricted between the seeds by oblique linear depressions. Unlike other leguminous seed crops grown in Hawaii, the pods of Cajanus rarely, if ever, shatter the seed. At the station mature pods have been observed to retain their

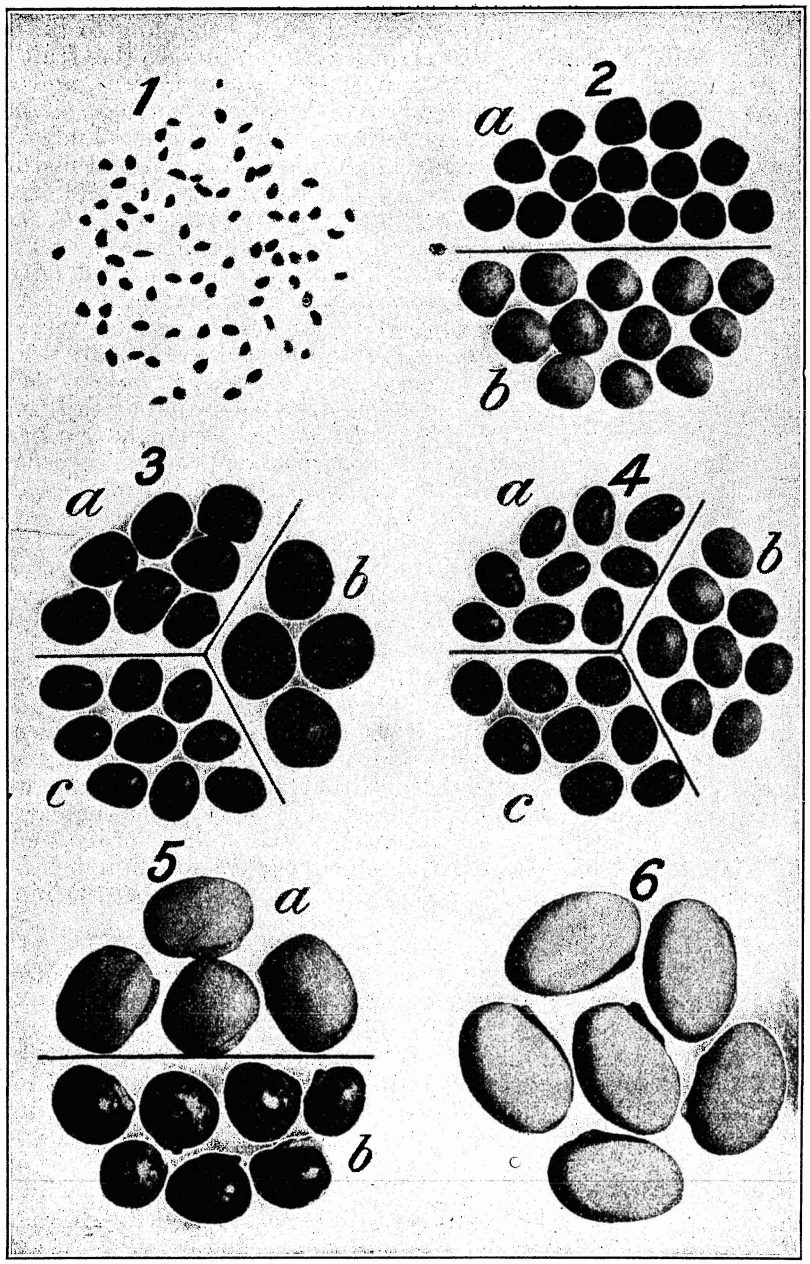

FIGURE 6.—Seeds of some leguminous plants: 1, Alfalfa; 2, pigeon pea, (*a*) *Cajanus flavus*, (*b*) *C. bicolor;* 3, cowpeas, (*a*) Wippoorwill, (*b*) Giant, (*c*) Iron; 4, soybeans; (*a*) station variety No. 478, (*b*) station variety No. 468, (*c*) station variety No. 477; 5, velvetbeans, (*a*) *Mucuna lyoni*, (*b*) *M. utilis;* 6, jack bean

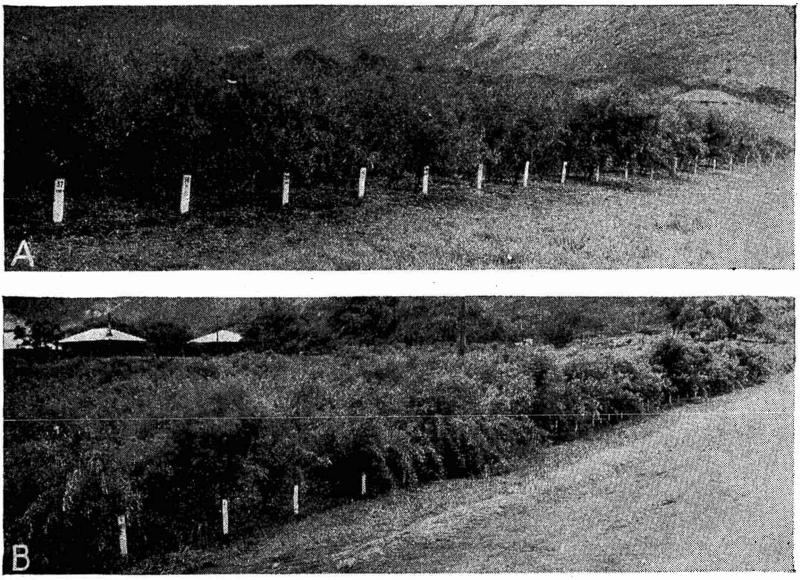

FIGURE 7.—Part of 590 distinct parents and their parents in the pedigree-breeding plats of pigeon peas, University of Hawaii farm: A, Planted November, 1928; B, planted December, 1929

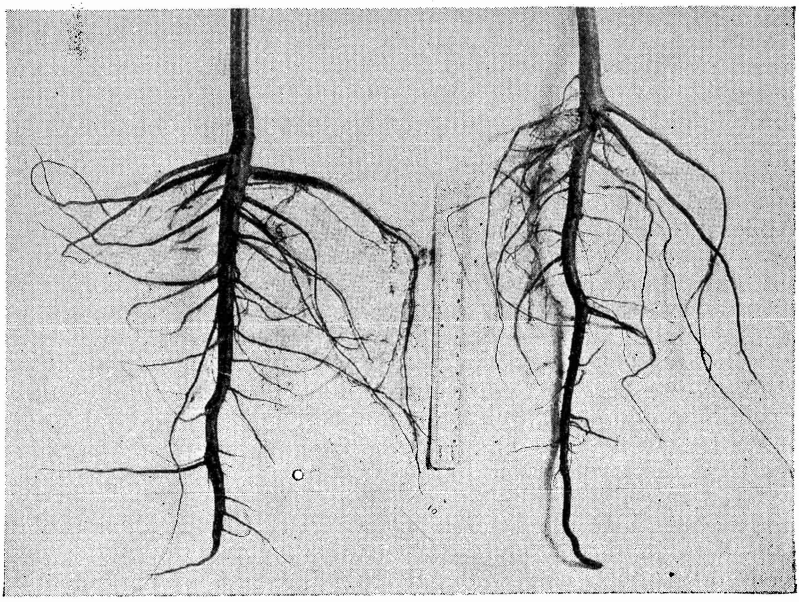

FIGURE 8.—Root development of pigeon-pea plant at six months in soil given good, deep tilth. Note the strong, deeply penetrating taproot. No other legume subsoils the land so well

seed for months well preserved even when exposed to heavy rain, strong wind, and the burning rays of the sun. The surface of the pods is glandular pubescent and secretes an aromatic fluid.

The flowers, few to many, are usually borne in loose, erect racemes, and are pealike. The standards are round and reflexed. (Pl. 1.) The wings are elliptic, clawed, and auricled. The keel petals are joined only at the angle of curvature, and are bluntly auricated. The reproductive organs are well protected within the keel. The upper stamen is free, the other nine are connate, with their filaments free for the upper fourth of their length, and alternately long and short. The ovary is pubescent. The style is the same length as are the filaments. The anthers are small and yellow. The stigma is capitate. Notwithstanding the many visits to the flowers by bees and other kinds of insects, cross-pollination infrequently occurs—less than 1 per cent when many varieties are grown together—largely because they are self fertilized usually a day or two before the buds open. In bright weather the flowers open early in the morning, and usually last for two days. Of the numerous flowers produced at the station, the greater number set seed under favorable weather conditions, especially when the flowering season is well under way.

The pigeon pea is a native of the Tropics and the subtropics, and will not withstand even light frost. Usually the plant is classed as a perennial, but certain varieties and a number of unfixed hybrids act as annuals. As a matter of fact, the plant is widely grown, especially in India, as an annual because it yields a poor second crop. According to Hooker (*10, v. 2, p. 217*) and Ochse (*20, p. 370*), in India and Java the pigeon pea thrives as an annual up to elevations approximating 6,000 feet, whereas in Hawaii the limit of altitude for all the varieties tested as perennials is 3,500 feet. Under a minimum temperature of 50° F. at night the plant at this height will seed as a perennial. (Fig. 9.) More than 30 varieties were introduced from India by the Hawaii Agricultural Experiment Station and the University of Hawaii for trial in Hawaii, but the home-grown progenies have not yet been widely enough tested at the higher elevations to determine their adaptability.

Apparently Cajanus has not often been found growing in the wild state. Grisebach, according to Watt (*25, p. 196*), states that the plant was probably introduced through slave traders into the West Indies and North America from Africa. The generic name Cajanus is derived from the Malayan name, Katjang. Some doubt exists as to whether the genus was originally a native of India or of Africa. In India it is extensively cultivated and has been one of the most important food plants for centuries. However, Watt (*25, p. 196*) says that no Indian botanist has recorded finding the plant in the wild or even in the naturalized state; hence, he concluded that it may have been introduced into India. Watt (*25, p. 196*), citing early botanists, mentions the plant as growing wild in the region of the Upper Nile, in Egypt, and in the cultivated and the wild state in the coastal districts of Angola, Portuguese West Africa. Loureiro, according to Watt (*25, p. 196*) mentions it as growing both cultivated and wild in China and in Cochin China. Seemann, as recorded

by Watt (*25, p. 196*), says it was introduced into the Fiji Islands by early missionaries. In Madagascar the plant is very important and apparently has been cultivated from ancient times. The plant is said to have been found growing on the mountains of Magelang, in central Java, Dutch East Indies, and according to De Candolle (*3, p. 334*) in Africa from Zanzibar to the coast of Guinea. This shows its wide distribution. The many Indian and Malay names by which the plant is known, according to Watt (*25, pp. 196–197*), would seem to indicate its ancient cultivation. Sturtevant (*23, p. 124*) states that Cajanus "certainly is one of the oldest cultivated

FIGURE 9.—Pigeon-pea plants growing in forest clearing at Glenwood at an elevation of 2,350 feet. The rainfall in this region is 120 inches a year

plants in the world, a fact attested by its presence in ancient tombs." Schweinfurth, according to Sturtevant (*23, p. 125*) says it was found in Egyptian tombs of the twelfth dynasty (2200–2400 B. C.).

The plant probably was introduced into Hawaii after the discovery of the islands by Captain Cook in 1778. Horace Mann, jr., and William F. Brigham, of Harvard University, collected the plant as early as 1864, when it appears to have been fairly well naturalized. Hillebrand (*9, p. 108*) states that Cajanus was of early introduction and was found growing near native dwellings. J. M. Westgate, director of the Hawaii Agricultural Experiment Station, states that he has seen a reference to the plant in which it was said to have been grown in the Territory of Hawaii at a considerably earlier

date. Wilson (*26, p. 10*) in the following interesting quotation from the manuscript diary of James Macrae, Scottish botanist, gives the earliest record known concerning the pigeon pea in Hawaii:

> One of the said white men took me to his little garden [Lahaina, Maui] which surrounded his hut. Here I noticed *Cytisus cajan* or the common pigeon pea of the West Indies, which he said was given him last year by the captain of an American whaler for coffee, together with some seeds of the Lima bean (*Phaseolus lunatus*), both of which were now in bearing for some time. But being as yet unacquainted with the way of using them for food, he always felt afraid to touch them for that purpose.

This may explain the presence of flourishing pigeon-pea plants in numerous kuleanas [4] throughout the Territory of Hawaii long before the station in Honolulu began distributing the seed. The writer began experimenting with the two known subspecies between the years 1906 and 1907 with seed that probably came from Porto Rico. Later a score of varieties were introduced into Hawaii from many foreign lands. These varieties have been used as a basis for breeding new varieties. At present about 600 established varieties, hybrids, and strains are being grown under comparative test by the Hawaii Agricultural Experiment Station in Honolulu, the University of Hawaii farm, the experiment station of the Association of Hawaiian Pineapple Canners, and private growers.

In Hawaii the plant ordinarily attains a height of 3 to 10 feet, depending on the variety, soil, moisture, and altitude, spacing of plants, and season of planting. Planted during the most favorable season in rich soil and supplied with optimum moisture, certain hybrid varieties have attained a height of 12 feet or more in one season. Occasionally such vigorous plants do not set seed until the second year. Under extremely adverse cultural conditions, certain other varieties grow only 2 feet high, but they may seed profusely and within 60 to 80 days from time of planting.

The pigeon-pea plant is known by many names. In India *Cajanus indicus flavus* is termed "thur," and *C. indicus bicolor*, "arhar." Other Indian names for the plant are del, dahl (dhal), rahar, toor, urhur, and, according to Elliott (*5, p. 294*), adhaki, tuvarai, and kandu; according to Duthie and Fuller (*4, p. 20*) arhar, dál, and arhuku. Watt (*25, p. 196*) says it is known in India as cadjan, tuvar (tuver), tur, thor, arar (oror), rahar dal, lahar, oroha, gela-máh, togari, kanalu, and peh-yen-klyung. He also noted that *C. indicus bicolor* is referred to as the Congo or Angóla pea, and *C. indicus flavus* as the no-eye pea in the West Indies. Lindley (*16, p. 31*) observed that it was called "doll" in the East Indies. African names for the plant include kolokoto, ndoti, and boese. By the French the plant is spoken of as embrevade, pois d'angole, and cytise des Indes. Ochse (*20, p. 370*) gives the Malayan name as Katjang or Katjang kayoo, the Javanese and the Madurese name as Goodé or Katjang goodé, and the Sudanese name as Heeris or Katjang heeris. In Hawaii it is occasionally spoken of as the Porto Rican pea. English-speaking races usually refer to the plant as the pigeon pea, by which term it is usually known in Hawaii. *Cajanus indicus* is the more commonly accepted botanical name, especially by

[4] Kuleanas are small Hawaiian homesteads granted the natives by royal favor.

European and Indian botanists. Some American botanists are inclined to favor the name *Cajan cajan*, but the greater number rightly adhere to the international code of botanical nomenclature. Barrett (*2, p. 349*) says the pigeon pea is known as "gandul" in Porto Rico.

IMPROVEMENT

BREEDING

The importance and practicability of improving the pigeon pea in quality and in adaptation to existence under different conditions of environment by systematic selective breeding, as in the case of other kinds of field crops, has been definitely proved. Breeding is being carried on extensively by the Hawaii Agricultural Experiment Station in Honolulu in cooperation with the University of Hawaii and other local agricultural institutions.

The plant lends itself admirably to the study of genetics, and in fact possesses many of the advantages that caused Mendel to select Pisum for his now-famous hybridization experiments. Study of inheritance in a number of crosses between pure-line varieties shows that some of the main characters closely follow Mendel's law. For instance, red flower standards are dominant over yellow; blotched or speckled seed dominate over solid colored, and maroon-blotched pods are dominant over solid light-tinted pods. Pubescent pods are dominant over glabrous; large, flat pods are dominant over small, round pods, and large seeds over small seeds. Four and five seeded pods are dominant over 3 and 4 seeded pods. Round seeds, slightly flattened, dominate over all others of widely different shapes, including spherical, oval, flattened, and irregular. The axillary flowers and pods dominate over terminal inflorescence. In stature blended inheritance is observable, very dwarf varieties when crossed with very tall varieties produce an intermediate type, and two varieties when crossed almost invariably produce a type that is taller and more vigorous than either parent. Crossing an annual type on a perennial type appears to produce perennial forms. This behavior has been found to remain constant, practically complete dominance for some well-defined differentiating unit characters being the rule.

When red dorsal standard sorts were crossed with red types, it was noticed that the solid red changed to red lacing, and when extremely tall and dwarfed forms were crossed the first generation was of intermediate height. Wherever dominance is apparent the second generation shows fairly definite Mendelian segregation as well as definite linkage between some characters. Dihybrid crosses appear to adhere rather closely to the 9:3:3:1 ratio.

A new hybrid form has now been established which has many of the desirable qualities definitely sought after. This new form, for the present designated as "New Era Strain X" (fig. 5), is characterized by strong, upright growth, deeply penetrating taproot, reasonably early maturity, and unusually heavy seed production. The originally selected mother plant of the first generation (station variety No. 218 being the maternal parent) during the first year produced 1,430 seeded pods weighing 1,587 grams, and 6,460 seeds weighing 1,150 grams, or at the rate of 4.5 seeds per pod. The proportion of

seeds to pods by weight was 73 per cent. The four subsequent generations of this hybrid yielded innumerable type forms, many of which are the equal if not the superior of their first-generation parent. Of the 200 types of this strain under test, many have attained a high degree of fixity.

In 1928 another exceptional hybrid was obtained by crossing New Era Strain D (station variety No. 218) and an unknown small-seeded Indian variety. This hybrid has been given the tentative designation of Strain Z. It yielded in the first harvest 3,225 pods weighing 46 ounces and over 15,000 seeds weighing 36 ounces, there being

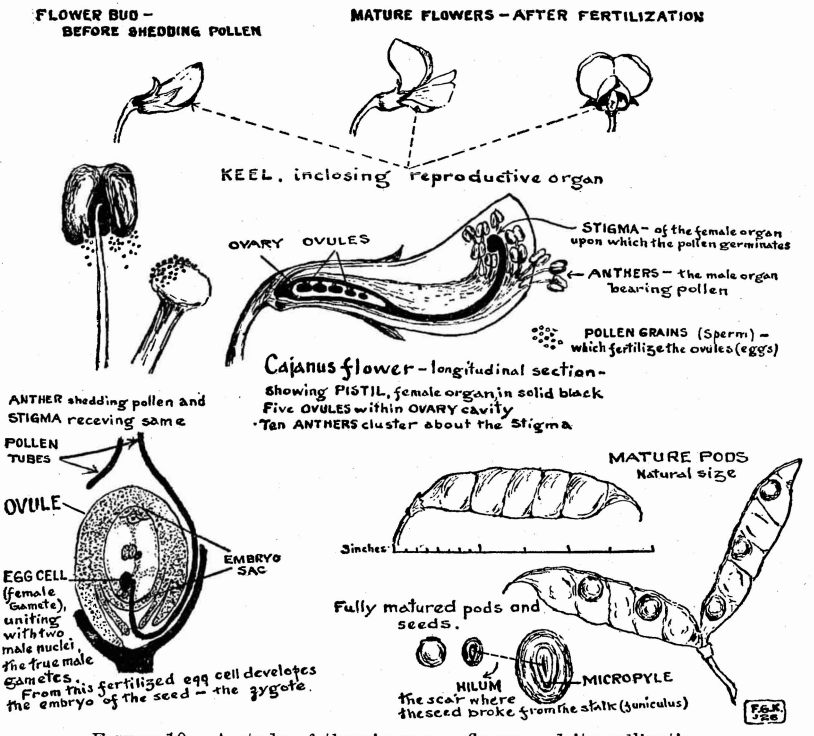

FIGURE 10.—A study of the pigeon-pea flower and its pollination

half as many pods as leaves. The seeds of this first-generation hybrid were of ivory-white color for the most part and of almost perfectly spherical form. This seemed to be a perfect type for culinary purposes so far as appearances were concerned. Of the thousand or more second-generation seedlings grown in 1929, no two were alike in the half dozen characters checked. The third generation has not sufficiently developed to determine its further behavior.

Innumerable other selections from both known and unknown crosses giving promise in 1929 did exceptionally well under the favorable weather conditions prevailing in 1930.

Cross-pollinating the pigeon pea is a simple process. (Fig. 10.) Students of genetics at the University of Hawaii have made hundreds of successful crosses during the last six or seven years. (Fig. 11.) The stigma shows receptivity for the pollen early in the flower-

bud stage—usually a day or two before the petals begin to unfold. Since self-pollination usually occurs just before the flowers open, the anthers must be removed for purposes of cross-pollination. Shortly after the flowers have been emasculated the stigma is supplied with pollen extracted from foreign anthers. When fertilization is effected the young pods form rapidly, whereas deficient pollination causes the flowers to drop without setting seed. At the University of Hawaii artificial crossing has been most successful on bright, sunny mornings. Since little or no pollen escapes from undisturbed plants the danger of accidental crossing is so remote as to make it rarely necessary to protect the breeding plants.

FIGURE 11.—Students of genetics, University of Hawaii, crossing the pigeon pea

At the Pusa Agricultural Research Institute in British East India, it is reported that considerable crossing of the pigeon pea occurs and that many of the seed stocks obtained from different parts of India have been badly mixed and contaminated by accidental hybrids. The writer has found in his work covering 20 years with hundreds of acres of pure strains of pigeon peas growing side by side and visited by pollinating insects, that natural crossing is comparatively rare in Hawaii, being considerably less than an average of 1 per cent. However, it may be that certain foreign varieties cross more freely than do those in Hawaii. The writer at the time of his visit to the Pusa institute in 1927 was told that an estimated 2 to 5 per cent or more of natural crossing takes place when different varieties are planted in adjacent rows. At the central station in Honolulu the New Era Strain D has been inbred for 20 generations. The thousands of acres of descendants of the original mother plant have bred at least 99.9 per cent true to type for over a decade. The introduction of off types has been the result of carelessness or of unknown circumstances.

To establish fixity in a hybrid type, a definite set of characters must be carefully and persistently selected for at least five or six generations, unless the desired combination is found in a chance homozygous form.

The agronomists of the Pusa institute, which has done some exceptionally creditable work on the pigeon pea, in a letter to the station wrote as follows regarding the genetic behavior of the species under their observation:

Characters best lending themselves to detection of heterozygotes and which show the kind of splitting taking place in this crop are general color and marking of standard, color of pod, and character of seed coat.

In regard to splitting in the general color of flowers and markings of the backs of the standard:

(1) A parent plant with orange flowers (backs of standard wavy red lines and diffused red color) gave rise the following year to 64 plants grouped as follows:
   (*a*) Flowers, pale yellow.
      Backs of standard without lines, 2 plants.
      Backs of standard with a few red lines, 4 plants.
      Backs of standard with red lines, 2 plants.
      Backs of standard with many red lines, 2 plants.
   (*b*) Flowers, deep yellow.
      Backs of standard without lines, 6 plants.
      Backs of standard with a few red lines, 2 plants.
      Backs of standard with many red lines, 4 plants.
   (*c*) Flowers, orange.
      Backs of standard without lines, 9 plants.
      Backs of standard with red lines, 13 plants.
      Backs of standard with many red lines, 12 plants.
      Backs of standard with many red lines and diffused red color, 9 plants.

(2) A parent plant with orange flowers (backs of standard red lined and diffused with red color) gave rise the following year to 47 plants grouped as follows:
   (*a*) Flowers, yellow or orange, differing as regards the markings on the backs of the standard.
      Backs of standard uniform deep red, 24 plants.
      Backs of standard orange without red lines, 4 plants.
      Backs of standard reddish orange without red lines, 12 plants.
      Backs of standard yellow orange with red lines, 7 plants.

(3) A parent plant with yellow flowers (backs of standard yellow with a few faint red lines) gave rise to 52 plants grouped as follows:
   (*a*) Orange flowers (backs of standard red lined and diffused with red color), 1 plant.
   (*b*) Yellow flowers (backs of standard without, or with only very faint, red lines), 25 plants.
   (*c*) Yellow flowers (backs of standard with many red lines and no diffused color), 26 plants.

In regard to splitting in color and markings of pods:

(1) A parent bearing pods with reddish lines gave rise to the following progeny:
   (*a*) Black, or reddish lined, 20 plants.
   (*b*) Nearly black, 1 plant.
   (*c*) Green without lines, 11 plants.

(2) A parent bearing green pods without lines gave rise to the following progeny:
   (*a*) Green, without lines, 14 plants.
   (*b*) Nearly black, 22 plants.
   (*c*) With black lines, 16 plants.

(3) A parent bearing pods with red lines gave rise to the following progeny:
   (*a*) Green, without lines, 10 plants.
   (*b*) With reddish lines, 29 plants.
   (*c*) Reddish black, 1 plant.

In regard to seed coat: This may be white, gray, red brown, purple, smoky, black, or spotted. Apparently there is no obvious connection between color of seed and color of flower. Similar seeds produce a wide range of flowers.

(1) A parent with whitish seeds tinged with violet and with violet spots gave rise to the following progeny:
   (*a*) White to brown, with or without a brownish ring at or around the helium, 20 plants.
   (*b*) Light brown, 1 plant.
   (*c*) Brown, with deep brown ring around the helium, 3 plants.
   (*d*) Red, 3 plants.
   (*e*) Smoky black, 3 plants.
   (*f*) Violet, 1 plant.
   (*g*) White to brown, with violet patches and spots, 26 plants.

(2) A parent with smoky black seeds marked with black gave rise to the following progeny:
   (*a*) Violet black, 1 plant.
   (*b*) Yellow brown, 14 plants.
   (*c*) Smoky without marks, 10 plants.
   (*d*) Smoky black, 19 plants.

(3) A parent with reddish black seed gave rise to the following progeny:
   (*a*) Black, 3 plants.
   (*b*) Red black, with black spots, 2 plants.
   (*c*) Red black, with red spots, 4 plants.
   (*d*) Dark red, 5 plants.
   (*e*) Brown with black spots, 3 plants.
   (*f*) Dark brown, 3 plants.
   (*g*) Brown red, 3 plants.
   (*h*) Yellowish, 7 plants.

At the Pusa Agricultural Research Institute investigations have been in progress for the purpose of isolating a unit species from the mixed field crop and isolating a type that will be resistant to wilt disease (*Fusarium udum*), to observe whether any of the pure lines show improvement over the mixed crop and whether variation in the incidence of the disease would indicate the direction in which further selection should proceed. The behavior of some of the isolated types throws light on the correlation between certain morphological characters and the quality of resistance. McRae (*17, pp. 44–47*) in 1923–24 reported that "progress was made in elucidating the factors governing the *rahar* (*Cajanus indicus*) wilt problem * * *." He found that the amount of rahar wilt due to seed-borne spores is small, and said that—

> seed sufficient for one acre of a selection susceptible to wilt was treated with two per cent formalin for twenty minutes to kill spores adhering to the seed, while seed for another acre was untreated. * * * In the first case two plants became wilted or 0.04 per cent. of the plants in the plot, while in the second case 66 became wilted or 1.4 per cent.

He next described tests of the rapidity of spread of the disease and concluded that "rahar as a leguminous crop will henceforth cease to form a part of the crop rotation."

McRae and his coworker Shaw (*18, pp. 208–212*) in 1925–26 reported progress with their investigation on the wilt problem in artificially inoculated fields, and began a study of the morphology of the selected plants for the purpose of classifying the resistant types. They concluded that selection could be classified—

> under two groups according to the type of branching. In the "A" series the branches diverge from the stem at a wide angle, while in the "B" series they tend to grow vertically parallel to the main stem, thus giving the plant a "poplar" habit. In the "B" series also the flowers are pure yellow without any red colour in the standards.

Kahn (*14, p. 19*), continuing the work, reported in 1926–27 finding about 20 different grains, 18 types of flowers, and 12 different pods, and stated that "natural cross-fertilization appears to take place in this crop on a large scale, as out of 265 different cultures which were raised from bagged plants only 76 were found to be almost pure."

Shaw (*21, pp. 21–22*) in 1927–28 stated that—

> among 76 pure types, which have been already obtained, 12 of the most promising were grown on a field scale to test their yielding power. * * * An analysis of the seed of these 12 types was made by the Imperial Agricultural Chemist and shows considerable variation considering that all the different types were grown within the relatively small Botanical Area. It appears that the morphological differences between types are correlated with physiological differences in their metabolism.

Shaw (*22, p. 21*) in 1928–29 gave a detailed account of the completed study on the isolation of the unit species in the pigeon-pea crop.

NEED OF CLASSIFICATION

To carry on genetic analysis on a comprehensive scale an adequate classification should be made of the established varieties of pigeon pea. Such a classification should be based on the best defined morphological characters of the plant, including, if possible, those of most importance economically. The following combined botanical and utility classification will, it is believed, include the many types of Cajanus now under test at the University of Hawaii farm. However, since forms differing from those already established are sure to follow, any system of classification will be inclusive only temporarily, and the following scheme is therefore at best only tentative and applicable for the present.

Structural Features

Since there is usually some correlation between structure and function in plants, morphological characters should be of great value in indicating economic uses to which the variety or strain may best be adapted. Thus, in the investigation reported, it has been observed that (1) tall, upright types almost invariably have deep penetrating taproots, and broad-spreading varieties more spreading and shallower root systems; (2) sparsely foliaged and limited branching sorts and dwarfed types are usually early maturing and drought resistant, whereas stocky types with dense, dark-green foliage are usually late maturing; (3) the heaviest podding and seeding types are intermediate in structure and maturity between the small, straggling, early maturing sorts and the compact, densely foliaged, late-maturing varieties; (4) the earliest maturing varieties usually behave as annuals, whereas the slower maturing varieties persist for a number of years almost in direct ratio to the length of time elapsing between seedings; (5) upright varieties are likely to bear the pods terminally, whereas spreading kinds carry the pods well along the branches; (6) stocky kinds are usually dense, dark-foliaged, and large, whereas spindling types have light-colored, sparse foliage; (7) the low-growing types are mostly of this kind, although some of them may become large; and (8) vigorous varieties respond to intensive culture, such as in soil of reasonable depth and fair tilth, and

supplied with fertilizers and water for irrigation, whereas scrawny and early maturing sorts make their best growth under adverse cultural conditions, such as in soils that are dry, badly prepared, and in poor tilth.

Many characters are concerned with color of seed coat and pod, and distribution of color as, for example, in bicolored flowering varieties which almost invariably bear pods blotched with red on a green background. The seeds of such varieties are usually spotted or blotched. Yellow-flowered sorts usually bear solid-colored seeds and pods.

A knowledge of these correlations should prove to be valuable to both the breeder and the planter in selecting varieties of pigeon-pea plants suitable for their conditions and purposes.

Classification Factors

Since this classification scheme is based on differences in the structures and habits of the different groups, the plant features of greatest use for purposes of identification should be arranged in the general order of their taxonomic value. These the writer assumes to be as follows: Color of blossom; color of testa; form and size of seed; formation, size, color, and pubescence of pod; habit of growth of plant; leaves and stems; roots; and chemical composition of plant.

COLOR OF BLOSSOM

The blossoms of the two subspecies, *Cajanus indicus flavus* and *C. indicus bicolor*, are solid yellow, except that in the latter the dorsal side of the standard is a deep, solid red. The innumerable sport and hybrid varieties resulting from crossing these two subspecies show variations only between the two color schemes, and the petals show little red except for the standard, which is rarely a solid red on both sides. These markings do not appear to be affected by environment, and are remarkably stable in homozygous forms.

COLOR OF TESTA

The color and markings of the seed coats range from ivory or light grayish white to very dark maroon or purple, and in appearance are nearly black. Brown-tinted seed coats predominate in all the types under test. There are all degrees of speckling and blotchings. These color markings are as well defined and as stable in Cajanus as in any other class of leguminous seeds. Like most other kinds, the pigeon-pea seed has a tendency to turn dark with age and exposure to light.

FORM AND SIZE OF SEED

The seed varies from a considerably flattened to an almost perfectly spherical shape. The seed hilum in most varieties of Cajanus is not so good a distinguishing feature as in many other kinds of legumes. In size the seed is less variable even between extremes than is the case with most other leguminous genera. It may for the sake of convenience, however, be classified as large, medium, and small.

FORMATION, SIZE, COLOR, AND PUBESCENCE OF POD

Pod formation follows two general modes, (1) dense clusters of pods on terminal branches, forming there in a blunt apex, with a slight distribution on the lower and lateral branches, and (2) a comparatively even apportionment of pods over all the branches and stems as in station variety New Era Strain D. Perhaps these structural differences in the pigeon pea, together with the correlated, tall, upright, late-maturing growth in the former type, and the low, more spreading and earlier maturing habit of the latter type, are among the first classification features that the practical planter or large breeder should observe. These are among the more important characters when the agronomic value of the plant is considered.

In size the pods in different types vary greatly, ranging from 2 to 4½ inches in length and from one-fourth to one-half inch in width. The pods may be cylindrical or flat, but are rarely of smooth, even structure like those of many other kinds of legumes, probably because of the characteristic constrictions between the seeds formed by oblique linear depressions and the varying curvature of the pod. The number of seeds per pod range from 2 to 6, rarely 7 or 8. The number of seeds per pod is a fairly constant factor.

The immature pods range from light green to deep maroon in color, with varying degrees of blotching. The mature pods range from straw yellow to dark purple, with intermediate types that also include blotched and striped markings.

The pubescence of pods, both in the green and in the mature stage of their development, may be almost absent or profuse to dense, and may vary in color from light to dark green. Some pods contain cells that secrete oil, whereas other are comparatively free from oil-bearing cells.

The pods of all varieties possess the remarkable characteristic of retaining the seed; hence this factor need not enter into the present classification scheme.

HABIT AND GROWTH OF PLANT

The pigeon pea ranges from 2 to 12 feet in height. Although this character varies greatly under different environments and cultural conditions, especially degree of soil moisture, the groups may readily be classified as dwarf, tall, and medium. In form the varieties may vary from a spread of branches equal to the height of the plant to very tall and slender, resembling in the latter respect the Panax. None of the branches are prostrate, although in some instances the plant droops under a heavy weight of seed. Height and form, although influenced to a marked extent by conditions of growth, constitute an important characterization in the work of describing a variety or assigning it to agronomic uses and in genetic analysis.

The length of time required by the pigeon-pea plant to develop a mature crop, or to attain maximum vegetative growth, ranges from about 100 days for the earliest annual varieties to more than a year for the latest maturing varieties. Only in exceptional cases do plants require more than a year in which to mature the first crop of seed. Nonflowering or imperfect or distorted flower types

have been found in very rare instances. Fall and winter plantings take longer to mature their first crops than do spring plantings, probably because the temperature then is lower and the amount of moisture greater. Photosynthesis, however, may play an important rôle as it does with the soybean. New Era Strain D, if planted between October and January, inclusive, usually matures the first crop of seed from April to May, inclusive. If planting is done between February and April, inclusive, the first seed crop will mature from July to August. In this variety a second crop of seed invariably matures before the end of the year, usually within 100 days following the harvesting of the first crop, whether done by cutting, mowing off the pod-bearing branches, or by cattle on pasture. Thrifty plantings, 3 to 5 years old, are commonly found. In such instances the crop may have been harvested 10 times. These characteristics are of great agronomic value.

LEAVES AND STEMS

The leaves may be classified as small, medium, and large, pale green, dark green, and a medium shade between the two extremes, pubescent and glabrous. There is, however, no marked difference in the prevailing types in these respects.

ROOTS

Unfortunately most of the varieties studied were tested at the University of Hawaii farm in the Manoa Valley, where the soil is underlain by a hard, impervious gravelly clay. Under these conditions the root system of all the varieties is inclined to be shallow and spreading, rarely penetrating deeper than 3 feet. Most of the roots feed within the first 12-inch level. However, the taproot has been found to penetrate deeper than 5 feet in similar soils after they had been subsoiled and well aerated.

There appears to be a rather definite differentiation in the amount of root type and mass and in the penetrating power of roots in the different classes. Tall, upright varieties produce longer and more deeply penetrating roots, whereas spreading types produce shallower, more spreading, and denser root systems. The different classes also apparently differ in the production of nitrogen-storing nodules. Under favorable conditions, however, all the varieties are abundantly supplied with large clusters of nitrogen-storing nodules.

CHEMICAL COMPOSITION

Too little analytical work has been done on the different varieties to determine whether their chemical composition differs significantly because of inherent qualities. The results of such analyses as are available from widely separated sources agree fairly well with those obtained with other leguminous plants grown under similar conditions.

With the above characteristics well defined, the breeder should have little difficulty in planning a series of group keys similar to those prepared by Etheridge and his coworkers (*6*).

SUGGESTIONS

Pure line or pedigree methods are commonly used in breeding self-fertilized plants, such as the legumes, for improvement. Under these methods each plant resulting from each cross in each generation is carefully studied. After the second or third generation has been established only the plants of the most promising lines or families are closely studied. Obviously there is a limit to the number of plants that can be handled in this intensive way because of the amount of labor and the expense involved.

The work of watching for superior plants is so important, however, that the writer early devised the following simple method for testing out large numbers of hybrid stocks efficiently and economically. It has more recently come into rather wide usage in cereal breeding under the name of "bulked-population" method. It consists essentially of producing large populations of progenies by hybridization and of planting the seed in bulk or en masse for 5 to 10 generations, regardless of relationship. From the progeny careful individual or mass selections are made year after year, or until such time as superior types have become firmly established or fixed. This, by reason of their natural inbreeding, takes place automatically. Thousands of pounds of pigeon-pea seed resulting in hundreds of thousands of individual hybrids have been grown in Hawaii by this method for many years. Some of the most promising new sorts now under cooperative test at the Hawaii Agricultural Experiment Station in Honolulu, at the University of Hawaii, and the experiment station of the Association of Hawaiian Pineapple Canners are the results of this method. Pigeon-pea growers in general and breeders in particular should make the most of this simple method by testing out many hybrid forms with little effort and small expenditure of money. Probably the only drawback to the method is the indiscriminate recrossing of some varieties or near varieties. However, thus far the writer has experienced no such difficulty.

The relative proportions of homozygous and heterozygous plants in any generation, assuming independent segregation, may be calculated by the general formula $h = 1 - \frac{(2^n - 1)^m}{(2^n)}$, as suggested by Babcock and Clausen (*1, p. 320*), where h equals proportion of homozygotes, n equals number of generations, and m equals the number of pairs of factors involved. Thus, with five pairs of factors, including medium, tall, upright, deep penetrating taprooted plants, terminal inflorescence, large, 5-seeded pods, medium-sized solid-colored brown seeds, and yellow flowers, determined as constituting an ideal type, a bulked population of heterozygous individuals would contain about 14.2 per cent of heterozygosity after six generations. At the end of the eighth generation only about 1.2 per cent would remain and the strain would have become almost pure, there being 1+ off type of plants out of every 100 grown. If linkages (natural correlation) are involved, the time required to establish a pure strain would be materially reduced. Diseases becoming inherent in any of the superior strains of pigeon peas can be controlled by breeding resistant varieties, as is being done at the Pusa Agricultural Research Institute in India.

CLIMATIC AND SOIL ADAPTATIONS

The pigeon pea is a strictly tropical or at least semitropical plant and will not tolerate even light frost during any stage of its growth. In Hawaii the New Era strains make their best growth at elevations ranging from 100 to 1,500 feet, although the plants thrive from immediately above sea level to heights approximating 2,500 feet. The highest elevation at which the plant is recorded as having produced mature seed in Hawaii is about 3,500 feet, and then only in well-sheltered localities.

In British East India along the slopes of the Himalayas the pigeon pea (rahar) is reported to do well at elevations of 6,000 feet,[5] whereas in Hawaii varieties repeatedly tested at heights of 3,500 to 5,000 feet failed to set seed. Mixed lots of seed containing over a hundred varieties also failed to set seed at these elevations.

In the hope of finding hardy types that would be suitable for the uplands of Hawaii, the writer made extensive explorations in Malaya and in India in 1927, but was soon led to the conclusion that all the high-altitude varieties of pigeon peas in these regions are extremely early-maturing annuals which mature their seed in comparatively short growing seasons. The agronomists of the Pusa Agricultural Research Institute were of the same opinion and believed that, while such varieties show no great inherent difference in hardiness, they are, like northern grown maize, so early maturing as to be able to escape cold weather and frost.

About half a dozen early maturing sorts among some 14 varieties of Cajanus, collected in eastern India in 1927, and many early-maturing varieties that were introduced into Hawaii from India in earlier years are now in their second and third generations at the University of Hawaii farm and at the central station in Honolulu. At the end of the present season (June, 1930) there should be ample seed available for wide distribution for trial at elevations of 3,000 to 5,000 feet. Hawaii ranchmen especially have expressed the desire to obtain suitable varieties for the dry, but in many instances fertile, uplands, as, for example, at the Parker ranch, Waiki, Hawaii, where vast areas of land are in need of suitable legumes.

The crop when established at these elevations will most probably be grown as an annual rather than as a perennial, as is the case in the lowlands, except in extremely sheltered locations or during unusually mild winters. In any event, the crop once established should volunteer by reseeding itself sufficiently from year to year to maintain a satisfactory stand. A large percentage of the fully matured seed, when passed undigested in the droppings of pasturing stock, germinates and becomes established under what would otherwise be very adverse conditions. (Fig. 12.) This has been found to be true especially at the Kapapala ranch near Pahala, where the soil is very thin, outcropped, and underlain with hard, smooth pahoehoe lava on which little else will grow. The crop is similarly reseeded on the very sandy bench lands in the coconut groves near Kailua, on the

[5] Since the above was written, Ochse (*20, p. 370*) has reported that Katjang goodé is frequently planted throughout Java, but especially in the Preanger regencies, on hoomas, on paddy-field dikelets, or in native gardens, from the plains up to an altitude of about 2,000 meters (6,560 feet).

island of Oahu. The widely spread algaroba forests have been seeded to a large extent in this way.

Wind does much less harm to the pigeon pea than to most other crops, especially if the pea is planted in double rows. The plant is rather sensitive to salt spray, but will grow in a wide variety of soils ranging from sand (provided it does not contain an excess of sodium chloride—0.0005 gram per gram of soil) to heavy clay loams and stony types that are well drained. The plant will thrive in regions of heavy rainfall to upward of and even exceeding 100 inches per annum, and also under heavy irrigation, provided there is no standing water on the ground even for a few days. On the other hand, there are few other cultivated plants that are so drought resistant as is the pigeon pea. In good, deep, mellow soils, and even in compacted soils, the crop may thrive under a rainfall of 10 to 15 inches.

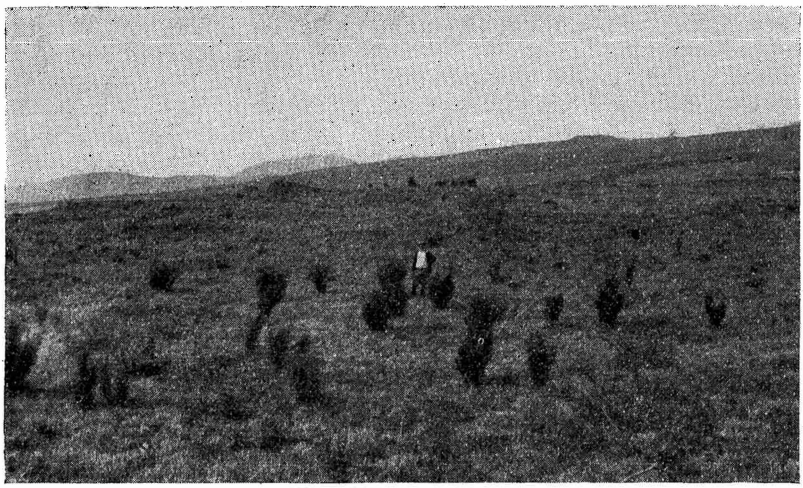

FIGURE 12.—Volunteer pigeon-pea plants "sown" by cattle running on thin lava soil area. These plants bear seed freely and thus add grain to the scant grass ration. (Kapapala ranch, Pahala, Hawaii)

Although the plant is tolerant of a fair amount of soil acidity and alkalinity, the most favorable pH values range from 5 to 7. The pigeon pea may become chlorotic when it is grown under conditions exceeding these limits, or when the phosphoric acid content is deficient, or the manganese content is excessively high in the soil, as is frequently the case in Hawaii soils.

The most favorable temperature for the plant under Hawaii conditions ranges from 65° to 85° F. In Hawaii the pigeon pea will withstand a minimum temperature of 50° under dry conditions, and a maximum temperature of +95° under sufficient moisture, provided that such other factors as drainage, fertility, and tilth are reasonably favorable. The plant thrives in strong sunlight and rarely sun scalds. On the other hand, too much shading causes the plant to make spindling growth and to bear thin, pale-green foliage and comparatively few pods and seeds. Climatic, soil, and moisture conditions favorable for Indian corn usually will cause the pigeon pea to make maximum yields.

CULTURE

TILLAGE

The pigeon pea is naturally deep-rooted, and therefore responds well to culture in deep, well-prepared soils. The surface soil also should be well tilled, and weed seeds should be destroyed before the crop is sown. Few other crops seem to be so slow in getting started as the pigeon pea. The young seedlings, although not delicate, make only spindling growth for the first month or two and then start off vigorously. The importance of clean culture in the earlier stages of development should be stressed even more than that of making a mellow seed bed, if the crop is expected to make a good start. Few of the many thousands of acres of pigeon peas in Hawaii receive during the entire long life cycle of the crop the thorough and careful soil preparation and after cultivation that is given a crop of Indian corn, which in corn-growing regions of the North occupies the ground for only a tenth as long as does the pigeon pea.

After the pigeon pea becomes well established it requires little cultivation. Some of the best crops receive only one good preparatory plowing and harrowing and no after cultivation to control weeds or to mellow the soil. However, it will pay to give the crop a reasonable amount of cultivation.

Grown in well-tilled and well-drained soils, the pigeon pea is plentifully and naturally supplied with root nodules. No instance has come under the observation of the writer in which the seed required artificial inoculation. Such inoculations have been found to improve the yield only in experimental sand cultures. A plentiful supply of root nodules is probably due to the growth in large numbers of wild reciprocal legumes in all kinds of Hawaii soils. The nodules are most abundant during the earlier stages of development. Only a few other kinds of legumes add more nitrogen to the soil than does a thriving crop of pigeon peas. The crop is especially valuable in this respect at 4 to 5 months of age, at which time it is making its most luxuriant development. At this period the pigeon pea is probably most valuable as a green-manuring crop at least on the lighter or more sandy soils. Heavy clay soils are benefited by plowing under the plants when they are older and more woody. At this stage of maturity of the plant the organic matter exerts a markedly beneficial influence on the physical properties of compact, tenacious soils.

For use as stock forage, the plant is of greatest value when in full pod, whether at 6 months or at 5 years of age. Regardless of the use to which the plant is to be put, reasonably good preparatory tillage and after cultivation are recommended for the crop under most Hawaii conditions.

Efficient tractor disk plowing costs from $4 to $6 per acre. Disk harrowing costs $2, and planking $1 per acre. Two complete tillages are ample for the seed bed, and will cost about $15 per acre under average favorable conditions. In impervious subsoils usually it will pay to subsoil the land to a depth of 15 to 20 inches. This probably will cost $10 additional, bringing the total cost of tillage to $25 per acre for a crop that should last for at least five years.

PLANTING

Distance between rows and amount of seed to be sown will depend upon the use to which the crop is to be put. For use as a cover or a shade crop and for green manuring, close planting is advisable. The pigeon pea should be sown thickly in rows 30 to 60 inches apart, or broadcast at the rate of 25 to 50 pounds per acre to give a full, thick stand. For pasturage, sowings should be at the rate of 2 to 4 seeds per running foot of rows spaced 5 feet apart. Many ranchmen plant in double rows 10 feet apart, center to center, and intercrop with forage grasses. (Fig. 13.) Grasses and low-growing legumes are greatly benefited when they are afforded protection by tall-growing pigeon peas and may receive additional benefit from their association with the heavy nitrogen-gathering host. Tall-growing varieties when grown as a temporary windbreak for fruit trees

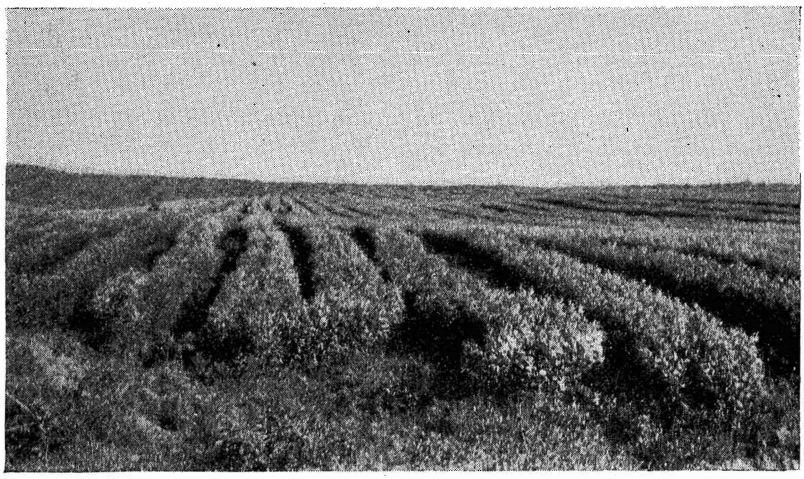

FIGURE 13.—Double-row planting of pigeon-pea plants intercropped with grasses at Kapapala ranch, Pahala, Hawaii

or in vegetable gardens may be planted in single or in double rows.

When the peas are grown for the table or for seed, most varieties, and especially New Era Strain D, do best if the sowings are made 1 foot apart in rows 5 feet apart. Such a planting will require about 5 pounds of seed to the acre since there are as many as 3,000 seeds to the pound. This rate of planting should allow for 8,750 plants to the acre. In pedigree breeding at the station the individual plants are set 2½ by 5 feet or 5 by 5 feet apart.

The ordinary 1-horse seed drill, adjusted with suitable seed and bottom plates, should be used to drop the seed in rows 5 feet apart. With this equipment a skilled workman should readily plant from 4 to 5 acres a day. About 10 acres may be planted per day by bolting two 1-horse seed drills together, or by using a standard 2-row corn planter. Twenty acres may be readily planted per day if a 4-row bean planter, drawn by a light tractor, is used. Seeding in a well-prepared bed costs about 50 cents per acre, depending upon the kind of planting equipment used. The seed may also be broadcast by ma-

chinery at 25 cents per acre, but such a procedure is not recommended. Prime seed costs 15 to 20 cents a pound.

With favorable soil moisture and a good seed bed, spring plantings emerge from the ground in a week or 10 days unless they have been too deeply sown. The seed should be sown at a depth of about an inch. Sowing the seed in winter or at the higher elevations or in wet seasons will cause the young plants to grow slowly, and frequently it will give weeds a chance to thrive. In such cases a hoe or a horse cultivator may be used if the operation is not too expensive.

FERTILIZING

The pigeon pea usually responds to treatment with phosphatic fertilizers, especially in the uplands. Reverted phosphate containing a considerable amount of free lime is preferable for acid and moist soils. Superphosphate gives better results on the drier soils. Nitrogen and potash are rarely beneficial, and this is also true of lime, except on very acid soils. Pigeon peas may respond to moderate liming. Not less than 350 pounds or more than 1,000 pounds of phosphate should be applied per acre when the fertilizer is to be drilled in at the time of planting. If broadcasting is to be practiced, at least a ton of the acid-treated rock phosphate should be applied, or upwards of 2 tons of the finely ground raw rock phosphate. Heavy applications of raw rock phosphate are recommended, especially when the pigeon-pea crop is to be grown for several years and finally is to be plowed under for green manure. Heavy applications are also desirable when the crop is to be grown as permanent pasture. Results of many experiments in Hawaii show that acid-treated rock phosphate is best applied at the time the seed is sown. Raw rock phosphate gives best results when it is applied in the fall and in the winter a few months in advance of planting. Rock phosphate can be used most economically with a long-time crop of pigeon peas. When the crop is finally plowed under the raw rock phosphate will have been reduced to a soluble form that is readily available to the succeeding crop.

IRRIGATION

As is indicated by Figure 14, the pigeon pea responds generously to a reasonable amount of irrigation during dry seasons, notwithstanding the fact that it is among the most drought-resistant cultivated crops known in the Tropics. Watering in excess of actual needs, however, retards seed production and encourages leaf growth. Yields of 25 tons of vegetable matter, including roots, per acre are considered to be excellent when the crop has been grown without irrigation. In Hawaii, however, a 6-month-old stand has been known to yield over 50 tons of vegetable matter per acre under irrigation. The irrigated plant shown in Figure 15 weighed 19 pounds at 25 months from time of planting. The $\frac{1}{50}$-acre plat in which this plant was grown yielded at the rate of 85 tons of vegetable matter. Where water for irrigation is profitably used in sugarcane production or for other field crops it can be made available to the pigeon pea after these crops have spent themselves. The pigeon pea can be made to yield as much forage as does alfalfa and at less than half the cost of the latter. The feeding value of the pigeon-pea forage when in fair pod equals or exceeds that of alfalfa.

HARVESTING, CURING, THRESHING, AND MILLING

The best time to harvest the pigeon-pea crop for hay or for milling as whole-plant meal, as was done extensively at Haiku, island of Maui, during the World War, is when a large percentage of the pods is mature, probably two-thirds to three-fourths of all the pods in sight, because a large part of the nutritive value of the plant is contained in the seed. So heavily do some strains seed that fully one-third of the weight of the terminal branches is made up of grain, and this proportion is sometimes greatly exceeded. One great advantage of the pigeon pea over many other leguminous seed crops at maturity is that its pods do not shatter their seeds even when they are roughly handled.

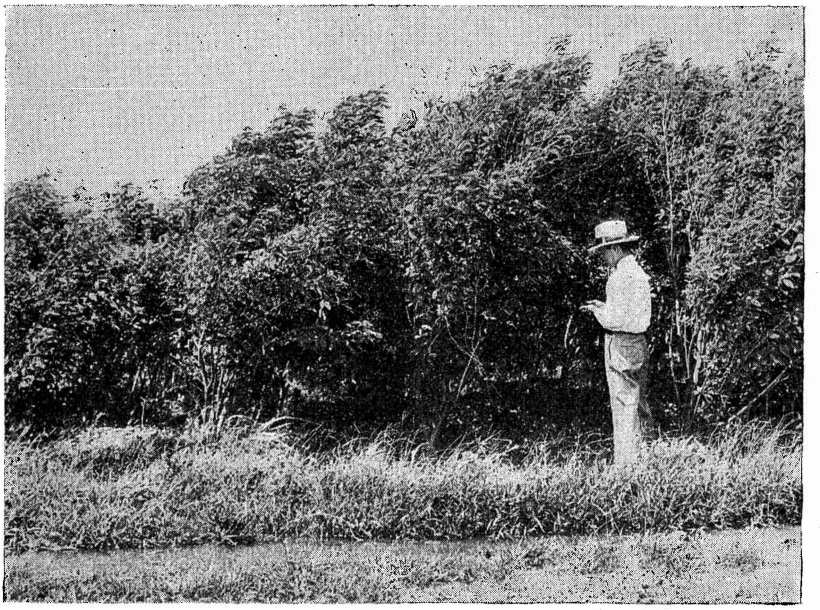

FIGURE 14.—Stand of pigeon pea New Era Strain X. Two rows on the right are irrigated and two rows on the left are not irrigated

Since the pigeon pea produces stiff, woody, but not tough, stems, it has been found desirable to harvest not more than the upper third, or, at most, the upper half of the plant unless the plant is very spindling and sparse, as sometimes happens on poor, thin soils, or during extremely dry seasons. In such instances the plant may be cut back or mowed to within 5 to 10 inches above the ground. This usually causes the plant to make stockier subsequent development.

The usual method of harvesting small areas of pigeon peas is to hand top the plants with a strong, short-bladed, Chinese grass hook, or sickle, or with a pruning knife such as is used in topping grain sorghums. An active workman should be able to harvest an acre of pigeon-pea tops, equivalent to 4 to 8 tons of fresh forage, bearing 500 to 1,000 pounds of mature seed, in a day.

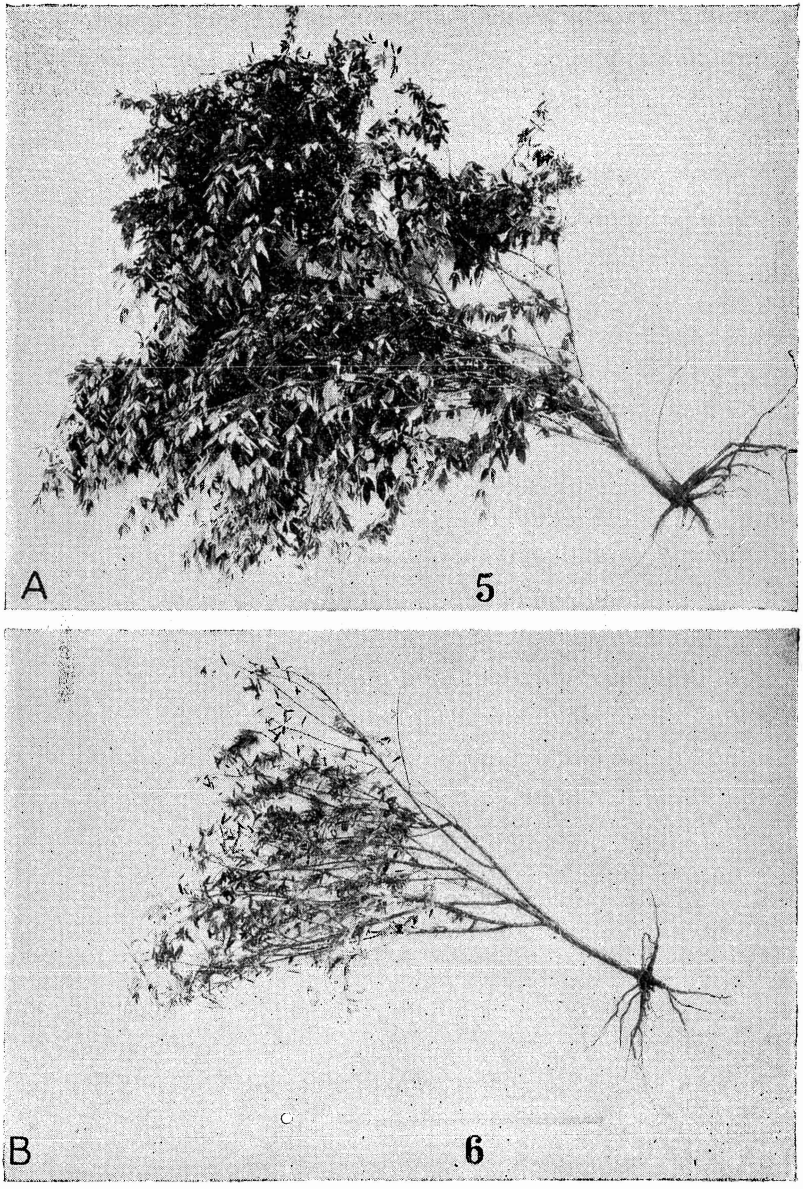

FIGURE 15.—Variety of pigeon pea New Era Strain D at 25 months' growth; A, No. 5, irrigated, weighed 19 pounds and produced 316 pods and 1,137 seeds; B, No. 6, not irrigated, weighed about 5 pounds and produced 455 pods and 1,430 seeds. (Rule, 1 meter long)

Some years ago W. D. Baldwin, of Haiku, had the sickle bar of an ordinary 2-horse mower adjusted so that the plants were mowed off at about 30 inches above the ground. This method made it possible to harvest 3 to 5 acres a day. The forage, whether hand topped or machine mowed, is laid upon the cut surface of the plant from which it was just harvested. If the sun is bright fully half of the free moisture in the plants will have been removed in 8 or 10 hours by the action of the trade winds. This preliminary wilting enables the forage to be loaded on the curing trucks or stacked without further hauling (*12 pp. 10–13*). Under favorable weather conditions and skillful handling, the forage is sufficiently cured in 6 to 10 days to be milled direct from the curing truck. Stored in large ground stacks, the crop requires a somewhat longer period to cure. Little loss of grain occurs in the curing and drying processes because, as previously stated, the pods rarely shatter their seed.

The maximum number of pods should have fully matured before the crop is harvested for seed by mowing the top growth. The pods may best be picked by hand. An active woman may pick upward of 200 pounds of ripe pods in 10 hours. When the pods are picked on contract the price paid varies from 1½ to 3 cents per pound. As the proportion of seed to pods is 50 to 60 per cent, the cost of harvesting the seed ranges from 3 to 6 cents per pound net.

Harvesting by mowing the pod-bearing stems followed by curing is more expensive for threshing than when the pods are picked by hand and does not permit of a material saving in the expense of producing a good seed product. However, when there is a labor shortage large crops can be handled by machine methods, and the forage and pods, after the seeds have been winnowed from the straw or plant débris, make an excellent shredded roughage that is much relished by all kinds of livestock. Picking by hand, while slightly more expensive than the other method, not only assures better developed seed, but also enhances the total yield, which may be double that recovered by the machine method.

Threshing the seed directly from the stems requires a rather strongly constructed machine. For this purpose double-cylinder bean and pea threshers have been used with much success by a number of local growers. The threshers have a capacity of three-fourths to 1½ tons of seed per day when all conditions are favorable. It is important that all the stems and the pods be well cured and that sufficient power be available before threshing is attempted. An even smaller and simpler pea huller is used for threshing simply the pods, and the strain on all working parts is very much lighter than when the seed is threshed directly from the stems. The pods alone thresh very readily when they are thoroughly dry, and about 1,000 to 2,000 pounds can be threshed within 10 hours with a 2-horsepower engine. Two men, or a man and a boy, are required to do the work most efficiently.

Whether threshed from the vine or from the pod, the seeds should be recleaned and graded. This is best accomplished by the use of a good fanning mill equipped with suitable sieves and riddles. Unless the seed has become discolored or moldy through improper handling, no further manipulation will be necessary. However, it may some-

times be desirable to pick the seed by hand to make it a merchantable product. This is an expensive process and adds considerably to the cost of the seed. As high as $4 per 100 pounds has been paid to have the work done properly. There are on the market foot-tread and power types of bean picking and sorting tables that would greatly facilitate this work.

Most leguminous seeds, such as cowpeas, soybeans, and the garden beans, are subject to weevil infestation to some extent, and the pigeon pea is possibly as susceptible as any to these ravages. The grower of this crop should provide for an air-tight storage chamber which can be periodically fumigated. At the Haiku substation a suitable compartment has been built by constructing double walls, floor, and roof of tongue-and-groove lumber laid crosswise with a layer of tarred felt between. The door is beveled and made to fit snugly against a felt face and is fastened with a strong refrigerator-door clasp. A compartment 6 by 6 by 6 feet is a convenient size for ordinary requirements, as it holds about 2 tons of bagged seed. The best fumigant to use is carbon bisulphide, the usual dose being 1 to 2 pounds of carbon bisulphide to every 1,000 cubic feet of space to be fumigated. The compartment described above would therefore require about one-fourth to one-half pound of carbon bisulphide per fumigation. The chemical should be placed in a shallow dish and set on top of the pile of seed to be fumigated. As the liquid volatilizes, the vapor flows over the sides of the container and, being heavier than air, seeks the lower levels. Fumigation should be continued from 24 to 36 hours. Those doing the fumigating should use every precaution not to inhale the gas or to bring a light near the vapor, which is very inflammable.

Pigeon-pea hay may be milled as a product resembling alfalfa meal, and when in full pod the pigeon-pea meal may be considerably more nutritious than alfalfa meal and fully as palatable as the best alfalfa product. For young cattle and horses the coarse woody fragments should be sifted from the meal.

In another publication (*11*, *p. 5*) mention has been made of the opportunity for enterprising and suitably equipped farmers to grow standard varieties of seed, especially the seed of the pigeon pea, the demand for which now greatly exceeds the supply. It is desired again to emphasize this fact. The very best seed strains may deteriorate rapidly in careless or inexperienced hands, but the seed business is, or should be, a highly specialized undertaking. It is likely that there will be an increasing demand for the pigeon pea once its exceptional merits become well known.

USES OF THE PIGEON PEA

Some years ago the Bureau of Plant Industry of the United States Department of Agriculture proposed extensive planting of the pigeon pea in both private and public bird reserves in the Southern States. In Hawaii pheasants, doves, quail, and domestic fowl have been observed to feed extensively on the seeds of this nutritious legume, evidently opening the pods without difficulty. According to Lindley (*16*, *p. 31*), the pigeon pea "is said to be so named because its seeds are the favorite food of wild pigeons.

Tall, deep-rooted varieties of pigeon peas make excellent windbreaks for all kinds of tender plants and crops, including young orchard and coffee trees, forest plantings, and vegetables. Indian corn and other nonleguminous crops when intercropped with the pigeon pea are greatly benefited by the protection thus afforded them, and even grass pastures make luxuriant growth when interspersed with even, widely separated rows of pigeon peas. Cattle and other kinds of livestock and fowl find welcome shelter among pigeon peas during cool, wet, windy weather, and shade from the sun.

The pigeon pea appears to make valuable bee pasture. Bees frequent the profusely flowering plants in great numbers whenever the weather is favorable.

Old, woody pigeon-pea plants are used for fuel in many places, and the charcoal made from the larger trunks is highly prized by makers of gunpowder. Results of experiments in Hawaii show that the charcoal is excellent for poultry, comparing very favorably in this respect with willow charcoal.

Watt (*25, p. 200*) states that "in Northern Bengal and Assam the arhar is specially grown as a food-plant for the lac-insect." When this statement was made the lac brought on the market about £144 gross per acre. Citing Jumelle, Watt (*25, p. 200*) says that silk was produced in Madagascar by silkworms fed on the pigeon pea, and suggests that Indian cultivators might find arhar silk "a possible additional source of revenue."

It has also been stated that decoction of the pigeon-pea leaves has medicinal properties, especially as an astringent.

Ochse (*20, p. 372*) notes that one becomes sleepy upon eating too many of the raw seeds. They may have slightly narcotic properties. However, he says the seeds are a harmless soporific since one rises refreshed from a somewhat more profound sleep than usual.

For a time it was thought that the pigeon pea was especially susceptible to attack by the root-knot nematode. Godfrey (*8, p. 12*), in exhaustive experiments with nematode-susceptible plants, found that a large number of cultivated plants and weeds are far more susceptible than the pigeon pea. In consequence of these findings, and observations by field men generally, the pigeon pea is gradually regaining its old popularity as a green-manure crop in pineapple culture. Godfrey (*7, p. 127*) says:

> The pigeon pea, in spite of the bad reputation it has in some parts, proved to be one of the most resistant legumes planted. After five months only the slightest infection was evident, a splendid stand of green manure was present, and the plants still growing. This crop deserves greater consideration on the part of the pineapple grower.

O. C. Magistad, chemist of the experiment station of the Association of the Hawaiian Pineapple Canners, recently told the writer of having investigated a field of pigeon peas yielding 35 tons per acre producing the equivalent of 500 pounds of nitrogen per acre for green-manure purposes on pineapple lands.

Elliot (*5, p. 294*) says: "The pulse, when split, is in great and general esteem, and forms the most generally used article of diet among all classes" in India, a fact which the writer can well attest. Of all the foods the writer ate in India during his recent agricultural explorations there, none was so appetizing and so sustaining as the

curried dried split pigeon pea (rahar) which was served with rice almost daily as a substitute for meat. As the European lentil is one of the most nutritious of the fabaceous plants, so to an even greater extent is the pigeon pea the staff of life of at least 10,000,000 persons in the Tropics.

Barrett (*2, p. 349*) states that about 30 distinct sorts of gandul are grown in Porto Rico. He also says that the plant attains a height of 3 to 16 feet, depending upon the variety; that the seeds vary greatly in color and in size; and that they make a highly nutritious dish before maturing. He added that the seed is believed to be rich in iron and in iodine. Porto Rican laborers in Hawaii prize highly the pigeon pea, either in its fresh state or dried. The young pigeon pea in pod is occasionally found in the Honolulu markets and brings as much as, or more than, the ordinary culinary pea. It has the additional advantage of growing throughout the year, whereas the common annual pea is restricted in its culture to the winter months. The French in Africa and in India were perhaps the first Europeans to appreciate the culinary value of the pea. However, Watt (*25, p. 199*) says:

> Sometimes the tender green pods with their contained peas are in India cooked in curry like French-beans. They constitute in fact an excellent VEGETABLE much neglected by the Europeans resident in India.

O. W. Barrett, in a letter to the writer, says, concerning attempts to can the pigeon pea (gandul) in Porto Rico:

> The Vincenty Hnos of Mayaguez, after some desultory preliminary tests, began canning gandul in the summer of 1928. They used pint and quart glass jars as containers, and rather unexpectedly had little or no loss from spoilage or breakage. The product is said to have been well flavored and kept its color as well as could be expected. To add to the attractiveness of the article and as proof that it was the true gandul of Porto Rico, a few unshelled green pods were inclosed with the green shelled peas so that they would show through the glass jars. A New York firm is said to have ordered 20,000 jars as a trial order to test out the demand among the 80,000 West Indian people living in New York. This enterprise, whether it succeeded or not, should fire the imagination of Hawaiian pineapple canners, who grow the pigeon pea extensively as a green-manure crop in their pineapple culture.

However, the pigeon pea is primarily known in the form of dry split peas as a source of food in the Tropics. Watt (*25, p. 199*) says that the pigeon pea (arhar) "enters very largely into the vegetarian diet of the Hindus and is sold either in the form of split peas or as pea-meal, of which sweet cakes are often made." According to Watt (*25, p. 199*)

> Decourtilz remarks that from the peas may be prepared a sort of sago much sought after by British and American sailors—an observation that recalls the parody on "The Mariners of England" who lived on "yellow peas."

Whereas the pigeon-pea plant does not appear to have been used extensively as a stock feed in the Tropics, Watt (*25, p. 200*) says that after the grain is threshed out from the cured podded shrub the leaves and empty pods form a valuable fodder, "and occasionally a pruning of the young shoots is taken and given to cattle. The outer integument of the seed with part of the adhering kernel is a favorite food for milch-cows. * * *" The pea or meal is largely used as a cattle medicine in India.

The Hawaii Agricultural Experiment Station between 1909 and 1911, and again in 1921, apparently first directed popular attention to the high stock-feeding value of the pigeon pea (*11, pp. 20–23; 12; 13, p. 20*). Since then many thousands of acres of land have been planted with the pigeon pea to supply pasturage and soiling crops for the cattle.

FEEDING VALUE

Cattle fed wholly on pigeon-pea pasture have gained in weight from 1½ to 2¾ pounds per day. Such pastures have been used primarily as finishing or fattening paddocks. The carrying capacity of good pigeon-pea pasture has ranged from 1 head to 2 acres to 1½ head to 1 acre. (Fig. 16.) Authentic records show the produc-

FIGURE 16.—Three-year-old field of pigeon peas with carrying capacity 1 to 1½ head of cattle per acre throughout the year. Such fields produce 800 to 1,000 pounds of body weight per acre per annum

tion of upwards of 1,000 pounds of prime beef per acre per annum. The average gains in body weight of a good grade of cattle having a run of good pasture and given careful management have been about 400 pounds per annum per acre on areas upwards of 1,000 acres. Some stockmen prefer a grass-pigeon pea pasture in which the leguminous and grass herbage is about equally divided, especially for young stock. Horses, mules, swine, sheep, goats, and poultry, and especially cows in milk, thrive when pastured on the pigeon pea in pod whether the crop is grown singly or in combination with good grasses.

The feeding value of a product depends not only upon its composition and digestibility, but also and to a very large extent upon its palatability to the animals fed. Whereas there have been received some reports indicating reluctance on the part of certain animals to consume pigeon-pea feed, most feeders report that all classes of livestock readily learn to eat the crop without the addition of other feeds. This seems to be the case especially when the ani-

mals have access to the growing crop as pasturage. At the Haiku substation every animal was found to browse freely upon the growing plant or to relish it when cured and fed as hay or grain.

Thousands of cattle have been fattened with very favorable results at the Molokai ranch since 1910, and at the Haiku, Kaonoulu, and Haleakala ranches, on the island of Maui, which have been famous for their "pigeon-pea" beef for the last 10 years. More recently, these ranches, with a combined pigeon-pea pasturage exceeding 4,000 acres, have been increased by areas belonging to progressive stockmen on the island of Hawaii, especially in the Kau district, near Waiohinu and Pahala. These enterprises include the well-known Parker ranch with pigeon-pea areas exceeding 600 acres at Kahului, 1,000 acres on the Hutchinson Sugar Co.'s ranch at Kaalualu, and about 800 acres at the Kapapala ranch. These areas have been developed from rough grass pasture lands since 1925. The Hutchinson Sugar Co.'s enterprise at Kaalualu has pastured as many as 1,000 head of young cattle on 1,000 acres of land. A 100-acre field within this area has supported two mature head of cattle per acre for two years. The crop was 3 years old when the cattle were removed in 1929.

Notwithstanding the fact that this region naturally possesses excellent grass areas that have been improved by the introduction of superior varieties, including Paspalum grass, Rhodes grass, redtop grass, and Bermuda grass, 2-year-old steers have been found to make gains of 50 to 100 pounds per head in excess of straight grass pasturage over a feeding period of 100 to 200 days when pastured on pigeon peas. An experimental dairy herd of 10 Jersey cows, half of which were fed wholly on pigeon-pea products, including pasturage, hay, and milled feed, yielded 8 per cent more milk at the end of a 6-month period than did those fed wholly on the best imported feeds. When the feeds were reversed the pigeon-pea-fed cows produced 9 per cent more milk than the animals that had been changed from pigeon peas to imported feed. The "pigeon-pea" milk was produced at a cost of less than 5 cents per quart, as compared with the imported-feed milk, which cost over 9 cents per quart.

Breeding stock thrives especially well on pigeon-pea pasture. Harold Rice and other local stockmen have reported that calves running on good pigeon-pea pasture with their dams received little or no setback on weaning. James A. Gibb, formerly assistant manager of the Wailuku Sugar Co., reports that mares running on pigeon-pea pastures were far more certain to foal and develop good horses and mules than were those on good grass pasture.

Swine thrive on pigeon peas, but are likely to uproot even large plants and are therefore best fed soiled crops.

Sheep and goat feeding has been tried only to a limited extent, but results of tests so far are very promising. A small herd of Toggenburg goats in milk produced more milk at the Haiku substation when fed pigeon-pea products than when fed imported feeds. The pigeon pea makes an excellent feed for rabbits. Turkeys and chickens given the run of pigeon-pea pasture when the plants are in pod make excellent gains, and the former hatch good, rapidly

developing broods under the shelter of the mature plants. Pigeon-pea plants afford fine shelter for poultry yards and in addition supply considerable grain and green feed. Bees apparently gather nectar freely from the flowers.

Except when all conditions are favorable, as during the World War, when imported mill feeds were abnormally high in price and hard to obtain, it is questionable whether the practice of curing and milling pigeon peas in Hawaii is more profitable than that of importing milled stuffs. Results of past experience at the central station in Honolulu indicate the advisability of milling Hawaii-grown feeds (*12, p. 16*).

Table 1 shows the average percentage composition of pigeon-pea products.

TABLE 1.—*Average percentage composition of pigeon-pea products*

[Based on all available analyses made in Hawaii to Feb. 15, 1920]

Character of material analyzed	Moisture	Ash	Crude protein	Carbohydrates		Nitrogen	Fat
				Crude fiber	Nitrogen-free extract		
Fresh green forage [1]	70.00	2.64	7.11	10.72	7.88	1.13	1.65
Whole plant cured as hay and ground into meal	11.19	3.53	14.83	28.87	39.89	2.37	1.72
Seed and pod meal	11.45	3.85	17.65	30.73	34.53	2.82	1.49
Seed meal	12.26	3.55	22.34	6.44	53.94	3.57	1.46
Threshed pod meal [2]	13.30	2.66	8.75	35.44	39.22	1.40	1.03

[1] Upper third of plant with seed in pod. [2] By-product in seed production.

Table 2 compares the composition of the pigeon pea with that of other Hawaii-grown leguminous forage and green-manure crops.

TABLE 2.—*Percentage composition of the pigeon pea and other Hawaii-grown leguminous forage and green-manure crops*

Legume	Proximate constituents—						Fertilizer constituents—			
	Water	Protein	Fat	Nitrogen-free extract	Crude fiber	Ash	Nitrogen	Phosphoric acid	Potash	Lime
Alfalfa	75.45	6.04	0.42	8.75	7.47	2.87	0.97	0.23	0.63	0.34
Cowpea	84.65	3.17	.17	5.33	4.97	1.71	.50	.13	.51	.25
Florida velvetbean	82.20	3.50	.70	6.60	5.10	1.90	.55	.14	.57	------
Jack bean	76.81	5.21	.48	8.44	6.36	2.70	.83	.16	.65	.78
Soybean	75.10	4.00	1.00	10.60	6.70	2.60	.63	.14	.56	------
Koahaole (Leucaena glauca) leaves [1]	8.77	24.45	4.62	39.36	14.88	7.92	------	------	------	------
Koahaole (Leucaena glauca) seed pods (immature) [1]	10.97	20.80	1.55	37.04	24.13	5.51	------	------	------	------
Pigeon pea	70.00	7.11	1.65	7.88	10.72	2.64	.113	.25	.90	.42

[1] Unfortunately no analysis of the entire plant in the fresh state is available for comparison with that of the pigeon pea and the other feeds.

Not only is the pigeon pea rich in food constituents, such as protein and fat, exceeding in these respects the five leading other leguminous crops (cowpeas, jack beans, soybeans, velvetbeans, and alfalfa) grown

in Hawaii, but the plant is also a good source of vitamin A. To Miller (*19, p. 573*) probably belongs the distinction of having first determined the vitamin content of Cajanus. Working at the University of Hawaii in 1924 and 1925, she found:

> The plant meal is a good source of vitamin A, due probably to the large amount of green leaves in it, whereas the seed meal is a rather poor source. Both the plant and seed meals are excellent sources of vitamin B, which is characteristic of other legumes.

Miss Miller found that apparently very little of the antiscorbutic vitamin C is present in the cured plant. The experiments were confined to station variety of pigeon pea New Era Strain D.

In ash constituents the pigeon pea compares favorably with the other legumes. The potash and phosphorus content is exceptionally high. The fertilizing constituents, considered in terms of nitrogen, phosphoric acid, potash, and lime, are present in excess of those in the other kinds of legumes analyzed. On the other hand, the crude-fiber content slightly exceeds the highest found in alfalfa. The average moisture contained in the fresh material averages about 70 per cent, which is low in comparison with that of many other forage plants (*11, p. 31*).

PIGEON PEAS AS A COVER, GREEN MANURE, AND ROTATION CROP

Good farming means, or should mean, both permanent and profitable agriculture. No agriculture can be either permanent or profitable where the outgo of fertility from the land is greater than the return. For the maintenance of soil fertility, no agricultural practices have longer or better stood the test of time than green manuring and the systematic rotation of crops. In Hawaii no other crop is known that will lend itself more readily to a large variety of conditions than the pigeon pea. On account of its ready adaptability to soil and climate, its drought-resistant properties, deep-rooting habit, heavy production of rich, nitrogenous vegetation, perennial nature, and thrift under neglect, the pigeon pea is peculiarly well suited to follow the pineapple and sugarcane crops after these have spent themselves by exhausting the fertility of the soil. Resting the land is said to restore fertility, but a more effective means of restoring fertility is to change the use of the land by rotation of crops. The cropping cycles of sugarcane, pineapples, and pigeon peas in terms of time are rather similar. On an average, the two great staple crops of Hawaii have a cropping cycle consisting of a plant crop and two ratoon crops, covering approximately five years. This is likewise true of pigeon peas. Not only is it good theory but actual experimental practice has demonstrated that worn-out pineapple lands may be restored to their original, or to improved, fertility by allowing a crop of pigeon peas to occupy the land for a period equal to the time such lands were cropped to pineapples, the pigeon peas then being turned under as green manure.

This was demonstrated in a pineapple field 2 years old which yielded 20 tons of No. 1 fruit during one season. Pigeon peas were grown on this field for three years, and the entire crop was then turned under. The vegetable matter, including the roots, woody trunks, and foliage, was approximately 50 tons per acre. In addition to this final green-manure crop, much leafy matter was shed on the

ground beneath the plants so that in places a leaf mold an inch or two thick had accumulated. This leaf mold was difficult to estimate, but in three years it must have yielded fully 5 tons per acre of the richest kind of organic matter. Just before the pigeon peas were planted the pineapple crop on the same land collapsed at the end of the first harvest. The second crop, or first ratoon, of pineapples succeeding the pigeon peas, on maturing, carried safely into the second ratoon crop and yielded 16 tons per acre, a large percentage being No. 1 fruit. This has been found to be an extremely simple, efficient, and economical cropping system. In this case pineapples were rotated with pigeon peas, an 8-year to 10-year rotation, allowing four or five years to each crop. In this rotation each of the "crops" is a dominating factor for a permanent and profitable agriculture and therefore good farming.

It is believed that what is apparently proving to be beneficial to the pineapple crop will be equally beneficial to the sugarcane crop and any other crop requiring periodical replanting. Sugar planters and others may welcome so dependable a rotation crop that is not only suitable for green manure, but also valuable for stock feed and as a cover crop for the conservation of the soil against erosion, a controller of weeds, a general soil renovator, and finally a crop that requires no irrigation and very little tillage. Such a crop would mean only little extra time and expense more than the time-honored custom of leaving the fields fallow.

It may be practicable for many of the sugar and pineapple plantation owners to seed their otherwise fallow lands to pigeon peas. This practice would not only result in renovating the soil for the subsequent crop of sugarcane or pineapples, but it would enable the plantation owners to maintain considerable herds of cattle and other livestock; these in time would do much to increase the local supplies of food products, and the importance of this can not be overestimated in a scheme of permanent and economical agriculture.

PLOWING UNDER PIGEON PEAS

Although the pigeon pea makes tall growth and becomes woody if left to develop maximum growth, it may be plowed under with little difficulty. A 60-horsepower tractor equipped with four 28-inch disks and heavily weighted will handle the crop efficiently, especially if the plow outfit is run in line with the plant rows. The plant disintegrates and decays rapidly when the soil is reasonably moist. A second plowing may usually be made within two to three months. The land should be disk harrowed after the second plowing and let alone for another month or two before planting is done. A heavy volunteer stand may result when the pigeon pea is well supplied with mature pods at the time it is plowed under. This second crop will add considerable humus to the soil, is easily plowed under at almost any stage of growth, and decays rapidly.

Maximum vegetable matter may also be obtained from pigeon peas by cutting back half of the plant when in full pod and throwing the brush between the rows. Many of the seeds will germinate between the rows, but will die and add their organic matter to the well-decomposed original prunings as the parent plants close in

the spaces between the rows. This practice has proved to be especially effective in forming an extra cover crop to prevent or to control weed growth in wet seasons, and as a mulch when the season becomes dry and windy.

Results of tests have shown that either of the two methods outlined above may under favorable conditions add fully 20 per cent more organic matter to the soil than is obtained by growing and turning under the single crop.

Pigeon peas whether intended as a forage crop or for green manuring should be fertilized at least with phosphorus, as has been stated. The yield may often be doubled by fertilizer treatment. When the crop is plowed under, the phosphorus will be returned to the soil in addition to the extra vegetable matter. Fertilizer not only increases the yield of forage for cattle, but also improves its quality.

FIGURE 17.—Pigeon-pea twigs badly infested with the soft-shelled scale *Coccus elongatus*. This pest, although partly controlled by natural enemies, has, nevertheless, destroyed several hundred acres of pigeon peas on Maui and on Hawaii

INSECT PESTS AND DISEASES

The pigeon pea in Hawaii is attacked by a number of insects which, while not widely destructive, are troublesome in some localities. The most serious of these is the soft elongated flat scale *Coccus elongatus*. Occasionally it covers the stems and the trunks of the plant to such an extent as to cause it to die. (Fig. 17.) Ordinarily this pest is controlled by natural enemies, but during the past two years it has destroyed several hundred acres of good pigeon-pea crops on the islands of Maui and Hawaii. (Fig. 18.) The Territorial Board of Agriculture and Forestry has been asked to aid in eradicating the pest by introducing suitable parasites,

since control by spraying and dusting on extensive areas is impracticable.

In recent years a stem borer has made its appearance in several localities. This borer has not been identified, but apparently it attacks the plant only after the latter has been injured and has partly decayed.

Recently termites were found attacking one of the breeding plats at the experiment station in Honolulu. This infestation was caused by growing the plants in close proximity to an infested wooden culvert. Apparently healthy plants were also attacked.

The bean-pod borer, the larvae of the common blue butterfly *Lycaena boetica*, which was greatly feared when the crop was first planted in small lots, has not proved to be a menace. Nor have the

FIGURE 18.—Three-year-old field of pigeon peas destroyed by the soft-shelled *Coccus elongatus*

cottony cushion scale, the mealy bug, aphids, the Japanese beetle, and wasps given as much trouble as it was expected they would. Cutworms and army worms occasionally attack the young seedlings, but are not considered a menace. H. F. Willey, superintendent of the Haleakala substation, reports that in 1927 infested plants were submitted to Otto Sweezey, entomologist of the experiment station of the Hawaiian Sugar Planters' Association, who identified the pest as *Hieroxestis omoscopa*, which is common in the oleander forest near by.

The pigeon-pea plant is rarely seen to wilt suddenly, and when it does the cause is usually found to be a very dry season, and not any specific disease.

Recently Leach and Wright (*15*) published a paper on the collar and stem canker of pigeon peas, a disease caused by a species of Physalospora. M. B. Linford, pathologist of the experiment station of the Association of Hawaiian Pineapple Canners, states that he finds no evidence of this disease in the Territory of Hawaii.

Tucker (*24, p. 31*) reports that the pigeon pea in Porto Rico is attacked by anthracnose due to *Colletotrichum cajani*. The disease

causes spotting of the pods and the leaves and destroys the seeds. It does not seem to have invaded Hawaii, although occasional suspicious symptoms appear during long wet periods. Every precaution should be taken to safeguard this valuable crop from the diseases and pests that attack it in other countries.

Godfrey (*8, p. 12*), in experiments conducted at the experiment station of the Association of Hawaiian Pineapple Canners, has shown that the pigeon pea is not any more susceptible to nematode root knot than are most other plants suitable for green manure.

SUMMARY

The pigeon pea is a native of the Tropics and subtropics, and will not withstand even light frost. The most favorable temperature for its growth under Hawaii conditions ranges from 65° to 85° F.

The plant is grown in Hawaii from near sea level to upwards of 3,500 feet. It is rather sensitive to salt spray. A number of varieties, collected at elevations approximating 6,000 feet in British India in 1927, are under test for tolerance to high altitudes in the Territory of Hawaii.

The pigeon pea thrives in almost all types of soil, ranging from sand to heavy clay loams, but makes its best growth in a medium heavy loam that is well drained. In Hawaii the plant becomes a stout shrub, attaining its maximum growth the first or second year at a height of 5 to 10 or more feet.

The crop has occupied approximately 10,000 acres of land in the Territory of Hawaii during the last 10 years. Part of the crop is used for pasturing cattle, and the rest is grown for rotating with pineapples, for green manure, and to some extent for seed production. Pigeon-pea seed grown in Hawaii has been distributed to many parts of the tropical world.

The crop requires a reasonable amount of cultivation before planting is done but little or none after cultivation. It is well supplied with root nodules, and the seed does not require artificial inoculation in Hawaii.

The amount of seed to be sown depends upon the use to which the crop is to be put. Close planting is advisable when the pigeon pea is to be used as a cover or a shade crop or for green manure. For a thick stand the seed should be sown in rows 30 to 60 inches apart, or broadcast at the rate of 25 to 50 pounds per acre. For pasturing, seed should be sown at the rate of two to four seeds per running foot of rows 5 feet apart.

The plant is admirably adapted to the study of genetics. A classification scheme, based on well-defined morphological characters of the plant, is proposed for carrying on genetic analysis on a comprehensive scale.

Approximately 500 recorded hybrids are being tested under widely differing soil and climatic conditions by the Hawaii Agricultural Experiment Station in Honolulu, working in cooperation with other local institutions.

As a result of careful selective breeding, the station has developed a variety of Cajanus known as New Era Strain D, which has been inbred for 20 generations and is now extensively grown on the

islands. Some of the established hybrids having New Era Strain D as a parent are very promising.

During dry seasons the crop responds to a reasonable amount of irrigation. It increases in vegetative growth and decreases in seed production when irrigated in excess of actual needs.

The pods are borne along the upper ends of the stems and on small areas may be harvested with a short-bladed Chinese grass hook, or sickle, or with a pruning knife. Large areas are machine mowed.

The pigeon-pea plant has many uses. It makes an excellent windbreak, and is used as a cover and green-manure crop and for rotation. It may be used as fuel, and charcoal made from it is much prized for use in making gunpowder. It is also used as a food for silkworms and for lac insects, and has been proposed as a feed in private and public bird reserves. It is fed to all classes of livestock, with excellent results. The pigeon-pea flower is a source of honey. In fertilizer constituents the plant surpasses many other kinds of legumes. The dried split peas form a staple article in the dietary of many persons, and the plant meal is a good source of vitamin A and an excellent source of vitamin B. The seed meal is a poor source of vitamin A.

Few serious insect pests and diseases attack the plant in Hawaii, although the soft-shelled, flat scale has been found to attach itself to the twigs in large masses and occasionally to kill the plants.

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APPENDIX

PRACTICAL EXPERIENCE OF GROWERS

The following letters from representative growers of the pigeon pea in the Territory of Hawaii may be of interest to the reader.

ISLAND OF KAUAI

P. K. Clapper, superintendent, Mahelona Hospital farm:

"Have grown pigeon peas for three years as a soiling crop for dairy stock. We irrigate but do not fertilize. The crop is harvested two to three times a year. Estimated yields of green forage, 20 to 30 tons per acre per annum. Our plants pod freely and the forage is relished by our cattle fed pure or mixed with alfalfa or other forage. We consider the pigeon pea a superior feed as to quality and economy of production. We find that 10 acres of alfalfa produces greater feed value for dairy cows than 20 acres of elephant grass; and pigeon peas while they do not yield as much as alfalfa are of equal if not superior feeding value. Our first plantings are still thriving. We have a total of about 10 acres in the crop and plan to extend its culture."

C. B. Lambert, of the Kauai Pineapple Co.:

"Approximately 25 acres planted to pigeon peas. Too recent a practice to give much knowledge concerning the crop. The advantages as we see them are cheap planting, nitrogen fixing, easy to plow under when young, decomposes rapidly when young, penetrates the soil deeply."

ISLAND OF OAHU

J. L. Witmore, of Wahiawa:

"Approximately 500 acres in pigeon peas at present. We expect to increase this area. The crop can be grown at small cost and is more easily handled than grasses and perhaps some benefit is derived from the nitrogen gathered. Pigeon peas are perhaps more susceptible to nematodes than grasses, and weeds are not as well controlled as with velvetbeans or grasses. We do not find pigeon-pea seed difficult to secure."

(Since the above was written, the fields have given an estimated acre yield of 20 tons of green forage at six months' growth.)

R. C. Turner, California Packing Corporation:

"Approximate present area in pigeon peas 400 acres. We expect to increase this area. Advantages of this crop over others: It is easier and cheaper to handle, and is of value in increasing nitrogen content of soil. Disadvantages are still unknown, though I am not entirely satisfied that it does any more or as much good to the pineapple crop following as does Panicum grass. Do not find difficulty in securing seed."

D. C. Derby, Libby, McNeill & Libby, Waipio:

"Up to 1926 we had planted several thousand acres to pigeon peas. Switched over to Panicum grass at time of nematode scare. Do not think we will again plant them to any extent because intervening weeds harbor nematodes, whereas Panicum grass crowds out weeds. We prefer Panicum grass. While seed of pigeon peas is scarce at times, we produced large quantities of seed at one time which we were unable to sell at any price."

Honolulu Fruit Co. (Ltd.):

"In 1923 and in 1924 we planted 20 acres in pigeon peas and obtained good results. We have no old land available at present. We intend to do some more planting later on when we have suitable area for the purpose."

H. K. Castle, Honolulu:

"We have used pigeon peas as you know for a good many years and consider them a very valuable crop for pasturing purposes. It is a good feed, and cattle do very well on it. The pigeon pea is not a particularly hardy nor a long-lived plant in our experience, its age depending upon the conditions where it is planted. Where the soil is good and the moisture sufficient, I should say that plants should last seven or eight years, but in places where conditions are unfavorable they will survive a less time. They need particularly good conditions to do well.

"We are planning to plant considerable of the so-called koa haole. This plant has an analysis that compares favorably with others of its class and is hardier than pigeon pea, and very well liked by cattle. However, it does not do to plant the koa haole where horses are expected to be pastured, as it causes the falling out of hair in mane and tail."

Paul A. Gantt, animal husbandman and manager, Hahaione farm, Kamehameha School:

"In October, 1927, we planted about 3 acres to pigeon peas at the mauka end of our pasture, Hahaione. These have done exceptionally well and are still almost 100 per cent living in spite of two very dry years and rather heavy pasturage during the past year. They have really surprised me by the way they have continued to grow through the dry season. A year ago this summer was a very dry season with us, yet the pigeon peas continued to grow and make a beautiful showing when everything else around them, including koahaole[6] was at a complete standstill. * * *

"As a general rule, our cattle seem to prefer other forages to the peas and do not feed on them very much as long as other feed is available. We have noted this particularly with our dairy cows when trying to substitute pigeon pea tops for alfalfa. The cattle will consume less to such an extent that a decrease is noted in the milk yield and they will clean up both alfalfa and elephant grass before starting the pigeon peas.

"We have planted about 8 acres, a cultivated but unirrigated section. These have made a very fine growth and the ones which were planted early last fall have now been cut three times and fed to the cattle. They appear to respond very well to cutting even in dry weather provided they are not cut too low. * * *

"On the whole we are really very much pleased at the fine growth that pigeon peas are making at Hahaione.

"The most extensive technically conducted tests with pigeon peas, both as forage and for green manuring purposes, on the island of Oahu have been conducted at the University of Hawaii farm, in Manoa Valley. From 1 to 5 acres have been grown there during the last 10 years. The crop has thrived exceptionally well both with and without irrigation. Yields of forage upwards of 15 tons and of vegetation for green manuring upwards of 25 tons per annum have been harvested in successive years. Seed yields upwards of 1 ton per acre have also been obtained. The forage has been found to be palatable to and nutritious for dairy cattle and definite benefits in soil tilth and in fertility have resulted from plowing the crop under."

ISLAND OF MAUI

W. A. Clark, manager, Grove ranch and pineapple department, Maui Agricultural Co.—one of the first ranchers to plant pigeon peas in Hawaii on an extensive scale (exceeding 1,000 acres), especially for curing and milling as stock feed during the World War:

"Approximately 400 acres planted to pigeon peas and expect to plant another 200 acres within the next two months. We plan to continue this practice right along as we believe pigeon peas make a very desirable green-manuring crop [for pineapples]. We are not at this time in a position to state whether the pigeon pea is a better cover crop than the other legumes or grasses. We have no difficulty in obtaining seed for planting."

J. Walter Cameron, manager, Haleakala Pineapple Co. (Ltd.):

"We have at present about 100 acres in pigeon peas. We do not expect to have more than 200 acres in this crop at any one time. The advantages in favor of the pigeon pea is that it is cheaper to plant. The disadvantage is that it harbors a lot of unwanted weeds, unless the stand of peas is dense."

J. A. Templeton, superintendent, Libby, McNeill & Libby, Haiku, Maui:

"In 1924 we had here about 60 acres of pigeon peas which gave us a very satisfactory crop; we have not planted any since that time nor have we any plans for future planting. There is nothing in the results of this planting to enthuse us over the crop, but I hardly think this brief experiment would justify us in making any positive statement as to the comparative value of pigeon peas against any other cover crops. Pigeon-pea seed is frequently difficult to obtain here."

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[6] Koahaole means *Leucaena glauca.*

D. T. Fleming, manager, Baldwin Packers, Honolua ranch, Lahaina, Maui, who has grown the crop without intermission for many years, is probably the foremost advocate of pigeon peas for green manure in pineapple culture. Under date of June 1, 1929, he reported having 500 acres in the crop upwards of 4 years of age and growing at altitudes of 200 to 1,500 feet. The crop is both drilled in and broadcast. It is plowed under when in full pod and the resulting volunteer crop is plowed under when in seed. The estimated acre yields are 10 to 15 tons per crop. Mr. Fleming considers the pigeon pea to be an ideal manuring plant and finds that it withstands both wet and dry weather reasonably well, takes care of itself without further attention after planting, and volunteers well after having been plowed under in seed. Some of Mr. Fleming's outstanding success in pineapple growing is attributed to green manuring with pigeon peas. However, he states: "Our second cycle plantings [of pineapples] have been much heavier than first cycles, probably largely due to 2-year rest periods under pigeon peas. Honolua ranch is one of the few plantations that have produced fifth ratoon pineapple crops."

Haleakala ranch formerly grew the crop extensively for pasturage. Corn and other cultivated crops have been discontinued in recent years, the pigeon pea being the last to give way to the pressure of relatively high cost of tillage in comparison with natural pastures.

Harold Rice, prominent ranchman of Makawao, Maui, was formerly the most extensive grower of pigeon peas for pasturage in Hawaii, his area at one time exceeding 2,000 acres, among which were thriving patches 5 to 7 years old. He has reduced his holdings to about one-fourth of its maximum on account of the presence of the soft, flat scale (*Coccus elongatus*) and other pests, and because of the demands of superior lands for pineapple culture, which bring high cash rentals.

W. D. Baldwin, of Haiku farm, has been one of the principal seed growers of pigeon peas for the last 10 years and has distributed many tons of the seed. He is a staunch advocate of the pigeon pea as a field crop.

ISLAND OF LANAI

The island of Lanai at one time had planted several thousands of acres to pigeon peas for grazing purposes. However, no new plantings of pigeon peas have been made since the lands were taken over for pineapple culture several years ago.

ISLAND OF MOLOKAI

G. P. Cooke, president and manager of the American Sugar Co.:

"I hope by the end of the year to have about 1,000 acres in this crop. * * * The pigeon peas we have (645 acres) will not stand high winds. In November, 1928, high winds stripped the bushes of all leaves and pods, and it would have died out if we had not mowed down to about a foot of the ground with the power mower. As you know we have planted pigeon peas since 1910. During this time we have had to replant whenever the weather conditions were unfavorable. One year, on account of drought, over 200 acres had to be replanted."

K. S. Brown, who maintained 200 acres of pigeon peas for three or four years on his Molokai ranch, reports that his original plantings have died out from attacks by the white fly, Aleyrodidae.

ISLAND OF HAWAII

Planting of the pigeon pea on extensive areas, especially for grazing purposes, has shifted from the island of Maui to the island of Hawaii in recent years. About 2,500 acres are planted with the crop on Hawaii. The Kaalualu and Kapapala ranches have each over 500 acres in the crop and are extending their holdings. During the past year (1930) Kapapala ranch, carrying about 3,000 head of Hereford cattle with an annual marketing of about 700 head through to 5 years of age, have found their 600 acres of pigeon peas the greatest asset for maintaining well-conditioned cattle for market during this period of unprecedented drought.

In the aggregate, several hundred acres of pigeon peas are scattered throughout the Territory in small patches in plantation camps and on home grounds. One poultryman who is about to specialize in turkey raising is reported to have five acres in the crop in his poultry runs.

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